The . . . New Zealand . . Nature-Study Book.

E. K. MULGAN, M.A.

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The New Zealand Nature-Study Book.

A Guide to the Nature Study Section
of the New Syllabus.

BY

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PREFACE.

So much has already been written and spoken about the importance of Nature-study, that it seems almost superfluous to pursue the matter further. Most, if not all, educationalists agree as to its utility in stimulating mental activity, in arousing thoughtful interest, and in developing intelligence and resource. The child is better and happier for a knowledge of Nature—her wonders and ways—and afterwards becomes a more useful citizen, not only because of this knowledge, but also from having acquired the habit of reaching conclusions by investigation and experiment.

The aims of the subject are not so much to obtain information, as to observe, to reason, to conclude, and to acquire the habit of accuracy in thinking, and facility in verbal expression. Hence, to be a success, Nature-study must be based on observation and experiment, and any course which endeavours to displace this foundation, can result only in failure. This does not mean that all guidance and assistance should be withheld from the child-investigator. In the initial stages of the subject these are essential, and at all stages they may be found desirable. But such assistance should be given only when it becomes necessary either to remove discouraging difficulties, or to stimulate the pupils to further effort. A child who, even in a small way, has mastered the art of observing has learnt much, for he is then possessed of a power which, if developed and wisely used, will enable him to undertake useful investigation.

It must be clearly understood that Nature-study is not to be confused with botany, or geology, or any other of the natural sciences. It can be considered as science only in so far as it enables the child to understand some of the facts of Nature, on which natural science is based. But, in its dealing with such topics, it differs widely from the systematic study of any particular science, whose objective is continuous investigation of one group of natural phenomena. For the child, Nature-study is one subject, though it may deal with matters coming within the special domain of several of the natural sciences. In our treatment of this subject, we should steadily bear in mind that specialisation belongs to a later stage of child-life, and that our first object should be to lay a broad foundation. There are, broadly speaking, two ways of dealing with the subject, each claiming the support of a large number of enthusiasts. The one aims at arousing a general interest in the work, avoiding detail as far as possible, which it is thought would prove wearisome to children, and probably have the effect of creating a dislike for the subject—that is, the main object is to awaken an interest in the teachings of Nature, rather than develop accuracy in detailed observation. Those who advocate this view usually introduce the subject through a class reader devoted entirely to lessons of interest on Nature-knowledge, or rural science, as it is sometimes called. These lessons, illustrated and expanded by a capable teacher, must undoubtedly prove of great service in enabling children to appreciate and enjoy much that would otherwise be to them a sealed book, and in stimulating and developing powers of observation in a very real and very useful way. The other plan—the one that I have endeavoured to follow in these pages—is to lay special stress on details, for it seems a pity that a subject fraught with such possibilities for accuracy of observation, for close reasoning, and for bringing home to children the importance attached to detail, should not be utilised in such a way as to give prominence to these aims. Set forth in this garb, the subject will direct attention to such details only as children may reasonably be expected to appreciate and understand. Far from creating a dislike for Nature-study, this method of treatment will surround it with a greater interest, and, in addition, will furnish a training in habits of accurate observation and correct reasoning which must prove of inestimable value in the years that lie beyond the period of school life. Moreover, the power obtained by such a course of training is a very great source of pleasure to a child, who will realise in acquiring mastery of the subject that his field of enjoyment is enlarged and widened. On this phase, Mr. A. D. Hall, Director of the Rothamsted Experimental Station, says "I am more than doubtful also of the value of the many natural history reading books which are appearing. Without doubt they are relished by children, and they do teach children how to observe and what to look for. The danger is that reading takes the place of seeing; the mind of man is naturally lazy, and prefers to think it knows rather than to worry a thing out for itself."

It is not intended that any special division of the subject should be confined to any one department of the school. On the contrary, the subject should be begun as a whole in the lower classes, where simple lessons, suited to this stage, will gradually prepare the way for the more detailed and exhaustive treatment necessary in the higher standards. This plan of adapting the treatment to the capacity of the child will be found running through the foot-notes at the end of most of the chapters.

The importance of drawing in connection with Nature-study can hardly be over-estimated. Drawing is a mode of expressing thought and of recording observed facts, and demands both accuracy of observation and attention to details, which must make for the formation of habits of the greatest value to the child in after years. When and where possible, the objects under review should be drawn. The sketches may be rough, diagrammatic, and but crude reproductions of the original, but even these will leave behind a clearer and more lasting impression of what has been seen and learnt than if the lessons were unaccompanied by such aids. It is assumed that all teachers will recognise the truth of this, so that it has not been considered necessary throughout these pages to direct attention continually to the importance of drawing.

The necessity for co-ordination applies to Nature-study as well as to other subjects ; and by this is meant not merely that the lessons and courses should themselves be correlated, but that other school subjects should have a close and direct bearing on the Nature-study scheme. This scheme should, as far as possible, be connected with the child's surroundings—that is, it should deal with matters within the range of the child's experience. It should be made the means of cultivating fulness and accuracy of verbal expression, and so become a medium for language lessons. It should furnish subject-matter for exercises in composition. It should—as previously stated—be accompanied by drawing, and so link this subject to itself. It should provide material for exercises in various branches of handwork, and, if not continued throughout the school, should lead up to the science teaching in the upper classes. Still, it must not be forgotten that correlation and co-ordination have their limits, and that "correlation for the sake of correlation should be avoided."

A good deal has been said and written on the use of technical terms—some authorities recommending that they should be dispensed with altogether. With this view I entirely disagree. As the study of a subject progresses, it becomes necessary to enlarge the vocabulary, and to employ special terms to express additions made to the child's knowledge—indeed, the only terms which will adequately and accurately express them. There is no more difficulty for a child in the names *corolla* and *pollen* than in the words *chrysanthemum* or *dandelion.* The terms themselves are extremely convenient for both teacher and pupil, and if not acquired too rapidly, there is no reason why they should not be taught with the best results. The danger to be avoided is the clothing of the subject in its initial stages with a mass of technical terminology, which would undoubtedly have the twofold effect of confusing the mind and creating a distaste for the subject. Introduced slowly, however, and only when necessary, such terms will prove a very real aid in making the subject better understood.

All schools, even the smallest, should possess a museum containing collections of plants, animals, rocks, and minerals. Of these, many will be essential for purposes of illustration, and all will prove of value in familiarising pupils with objects either directly or indirectly connected with the courses of instruction. Too much importance, however, must not be attached to the collecting of specimens. That is, mere collecting, though useful in itself, is of very little real value so far as Nature-study is concerned, unless the specimens themselves be questioned and understood. In other words, the specimens must be examined, must be compared and contrasted with other forms, and have their relationship to these established. In addition to a museum, a garden and an aquarium should, where possible, form part of the equipment of every school.

Nature-study should not be confined to the school-room—indeed, if it is to prove the success its advocates hope for, it must lead to work being done in the field. This part of the subject, in numbers of schools, presents grave difficulties, which, in many cases, can only be partly overcome. Schools in the larger centres have but few opportunities for field-work, and smaller schools—even those within reach of plants or minerals—are constantly faced with the difficulty of finding time for work of the kind. Still, much can be done under the stimulus of enthusiasm and energy. Excursions undertaken with some definite object are of very great importance, tending, as they must, to invest the subject with greater interest and reality. If these become impossible, attention should constantly be directed to objects of interest in the neighbourhood, where pupils may be encouraged to apply beyond the school walls the experience gained during the lessons.

The book has been divided into three parts—the first dealing with Plant Life, the second with Animal Life, and the third with Minerals and Rocks. It is not to be supposed that the outlined treatment of these is the only one possible. Indeed, it is hoped that the chief effect of much of what has been written will be to suggest the kind of treatment needed, rather than to furnish working details. These it was, of course, necessary to describe, but other ways of dealing with the same things will no doubt be employed, and other phases of the subject investigated. Vegetable, animal, and mineral products have only been lightly touched on ; the work of the sea, of rivers, and of ice, the movements of the earth's crust, the functions discharged by lakes, the manifestations of volcanic activity (all of which can be so well illustrated in various parts of these islands) have hardly been mentioned at all, as the book has grown beyond the limits originally planned. The notes at the end of most of the chapters, it is hoped, will prove helpful in suggesting methods of dealing with the topics contained therein. Most of the plants referred to in Part I. are introduced forms. These have been chosen because of the greater readiness with which they can be obtained. Those teachers whose work lies in districts accessible to native bush, will find little difficulty in adapting the work to suit the conditions of their environment.

Through the kindness of the publishers, I have been able to include illustrations from *Animals of New Zealand* and other books. For much of the subject-matter in the chapter on native birds I am indebted to the work of Captain F. W. Hutton and Mr. James Drummond *(Animals of New Zealand)*. I have also to acknowledge the courteous assistance of Mr. D. Petrie, M.A., F.L.S., in the chapter on grasses.

The drawings for the plant and animal diagrams are from the pen of Mr. R. Carr.

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PART I.

PLANT LIFE.

I.—THE PLANT.

A plant is a living thing—it grows. When pulled up out of the ground it becomes dry and withered and finally dies. Moreover, when alive, it continually increases in bulk—sometimes indeed with great rapidity.

Parts of a Plant.—The examination of any flowering shrub will show that it consists of a **root**, by which the plant is held in the soil—a **stem**, which generally grows upwards from the ground and gives off **branches** spreading out on all sides and bearing **leaves**. The stem and branches also bear flowers, some of which develop into fruit and seed.

NOTE.—A course of lessons in Nature-study might well begin in the Primer classes, with the examination of the plant as a whole. The pupils should first of all grasp the idea that a plant differs from a piece of coal or rock—both of which are found in the ground—in being a living thing capable of growth, and that, like all other living things, when once dead, it not only ceases to grow but withers away and gradually disappears.

A large number of young plants should be available for the earlier lessons—both those with soft, and those with woody stems. An investigation of these will familiarise the pupils with the various parts of the plant, as well as with their names, and will emphasize the fact that all plants—at least all those with which they will have to deal,—are made up of the same parts. Some help may be needed here with the names of the various parts (root—stem—leaves, etc.), and in leading children to recognise and describe the positions of these. This, however, is unavoidable where little children are concerned—as the study of the subject progresses, assistance of the kind can be gradually dropped.

As it is necessary that pupils should be familiar with the general structure of a plant, it is imperative that this portion of the subject be mastered before the next lessons are taken up.

II.—SEEDS AND THEIR GROWTH.

The Bean Seed. Preparing the Seed.—It is necessary that the seeds should be softened before being examined; this is easily done by soaking them in water. The length of time they should be allowed to soak will depend on the temperature of the water and on the size of the seed. If the water be slightly warmed, the softening process will be considerably hastened. Peas and beans should be left in water for a couple of days, and before being examined should be sufficiently soft to be cut with a knife.

Examining the Seed. The Outer Surface of a Bean Seed.—Observe the flattened oval shape of the seed, with a depression at one end. Notice the black scar, *hilum*, which extends along the edge from the depression. Procure a bean pod, if possible, and notice that the scar is the place of attachment to the pod. Remove all moisture from the bean by wiping it with a dry cloth, and then squeeze it gently by pressing

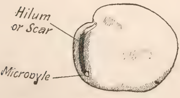

Fig. 1.—Seed of Bean.

against the flat surfaces. A small drop of water will ooze out at a point near one end of the stalk-scar. The little hole through which the water comes is called the *micropyle.*

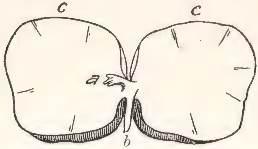

Fig. 2.—Seed of Broad Bean, showing the two cotyledons.
a, Main stem or plumule. *b*, Main root or radicle *c c*, Cotyledons.

The Inside of a Broad-bean Seed.—Remove the outer seed-coat, (*testa*) with a sharp knife or stout pin, beginning at the side furthest from the scar. Notice the colour of the seed coat and of the inner portion it encloses. Near the micropyle a little cone-shaped body will be seen—the *radicle.* Examine the edge of the seed opposite the radicle and the crack which divides the seed into halves. Inserting the edge of the knife into this crack, carefully separate the halves. This can be done without tearing either of them, for, although fitting closely together, they are really separate. These two swollen bodies are called *cotyledons* ; describe the shape of one of them. Make out lying between the cotyledons a little curved body—a continuation of the radicle—known as the *plumule.* Gently scrape the inner surface of one of the cotyledons and show, by pouring on it a few drops of iodine solution, that it contains starch.

As it may frequently be necessary to apply what is known as the "starch test," the following experiment should be gone through before treating the bean seed with iodine solution.

Prepare some starch solution, by boiling a small quantity of starch for a short time, allowing the whole to cool and the undissolved starch to settle down, and pouring off the clear liquid which remains. Empty a small quantity of the clear starch-solution into a test tube containing water and add a few drops of weak iodine solution—in which a small quantity of potassium iodide has been dissolved. The liquid will immediately turn blue owing to the formation of iodide of starch. Any portion of the plant, therefore, giving this characteristic blue colour on being treated with iodine solution, we may reasonably conclude contains starch.

The best way to prepare such a solution is to dissolve a few crystals of potassium iodide in a little water, and then add a small quantity of iodine until the solution is a pale amber colour.

Germination and early stages of growth of the Bean Seed.—In order to observe the process of germination and stages of growth, place some seeds of the Broad-bean in damp sawdust. A good number of seeds should be planted, and after the first thirty-six hours a few of these should be taken up every day or two and examined.

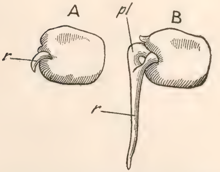

Fig. 3.—*A*, Germination of Broad Bean, showing radicle, *r*, just emerging. *B*, later stage, showing plumule, *pl*, beginning to withdraw itself from seed.

Under the influence of heat and moisture the seed swells up, and the radicle or young root breaks through the seed-coat at the micropyle. The radicle immediately begins to grow downwards (under the action of gravity) and, as it becomes larger and thicker, the seed-coat gradually opens exposing more and more of the cotyledons. In a short time a swelling appears at the upper end of the radicle, and the plumule, or young stem, forcing itself out of the seed, at once begins to grow upwards.

At the end of the plumule is a small bud which begins to unfold its leaves so soon as the light is reached. The cotyledons remain in the ground and gradually shrink up and disappear as the plant becomes larger ; though they often persist for a considerable time after the plant has come through the soil. The food material contained in the cotyledons has been absorbed by the plant and used up in the process of growth.

The seeds of the pea and other plants can be examined and studied in the same way.

Examination of the Maize Grain. A Maize grain, which is really a one-seeded fruit, in that it possesses both seed-coat and fruit-case, is a convenient form to examine next—more suitable than the Wheat grain the parts of which are smaller and not so easily identified. It is better, therefore, to defer the examination of Wheat grains until the structure of the Maize grain is mastered.

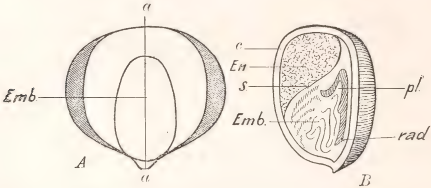

Fig. 4.—*A*, Side view of Maize grain, showing position of embyro. *B*, section of same grain through *a a*.
emb, embyro ; *rad*, radicle ; *pl*, plumule ; *s*, scutellum ; *en*, endosperm ; *c*, seed coat and fruit case.

In shape a Maize grain varies considerably ; looked at when lying on its side, it is broad and flat, tapering abruptly to a point towards its base. An end view shows it to be wedge-shaped, broad above and gradually narrowing below. On one flat side is a whitish oval depression under which lies the embryo.

If the grain be divided lengthwise by cutting it through the white patch from top to bottom, its structure can be readily seen. It consists of two principal parts separated from each other by a flat plate, the *scutellum.* Below the scutellum is the embryo, consisting of plumule and radicle, and above it is the *endosperm.* A drop of iodine solution will show that this consists largely of starch —being, in fact, the food stored up by the plant for the use of the seed during the earlier stages of germination. About half the grain is occupied by the endosperm.

The Wheat Grain.—The Wheat grain is boat-shaped and smooth, convex on one side and having the other deeply furrowed. A tuft of fine hairs covers one end, whilst near the other end on the side opposite to the groove is a white depressed patch overlying the embryo.

If the grain be now divided with a sharp knife lengthwise along the groove, its similarity in structure with that of the maize grain will at once be apparent. The scutellum is easily found, but the embryo requires to be looked for. It will be noticed in this case that the embryo forms but a small proportion of the seed, the bulk of which is occupied by the endosperm.

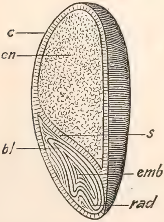

Fig. 5.—Section through Wheat Grain.

emb, embyro; *rad*, radicle; *pl*, plumule; *s*, scutellum; *en*, endorsperm; *c*, seed coat and fruit case.

Germination of Wheat and Maize.—As in the case of the Bean seed, if a few grains of Wheat and Maize be placed in damp sawdust, or in the soil, for some days the various stages in germination and growth can be observed. For germinating seeds, sawdust has the advantage over soil in that it is cleaner and more easily removed from the growing plant when this is taken up to be examined. In order to follow the stages of growth a number of grains should be planted and a few raised and examined each day.

The grain at first absorbs moisture, and then swells up and begins to show signs of life at the white patch which marks the position of the embryo. Here instead of one root —as in the case of the Pea or Bean—a number of small fibrous roots begin to show themselves almost at the same time. Unlike the radicle of the Bean, they do not grow directly downwards, but spread themselves out in all directions in search of food. Growing from the same part of the grain, and quite close to the roots, is the rounded stem which gradually curves upwards to the light. If, before reaching the surface, the stem be cut through lengthwise, it will be found to consist of a sheath, the cotyledon, covering a green rod-like body, the stem. So soon as the plumule reaches the surface, or even before this, the stem breaks through the tip of the cotyledon. As it continues to grow, the sheathy leaves gradually unfold into the long narrow blades which form the leaves of Wheat or Maize.

The endosperm, which originally formed a considerable part of the grain, gradually shrivels up and disappears as the plant continues to increase in size. The food material which it contained has been absorbed by the scutellum and conveyed to the young plant. It is in consequence of the nourishment thus obtained that the plant is able to grow at a time when it has neither roots to obtain food from the soil, nor leaves to absorb carbon-dioxide from the air.

Comparison and contrast of results obtained. —We are now in a position to compare and contrast the structure, mode of germination, and growth of the seeds we have been examining.

They are all hard and dry, and require moisture and warmth to induce germination. In every case growth begins in the embryo, and is promoted at first by a food-supply stored up in the seed or grain itself; this food material becoming exhausted as the plant continues to grow.

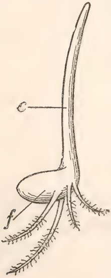

Fig. 6.—Wheat Seedling.
c, cotyledon. *f*, furrow.

On the other hand certain marked differences are at once apparent. The Pea and Bean seeds inside the testa, or seed-coat, are composed entirely of embryo, consisting of a radicle, a plumule, and **two cotyledons**, whereas the Wheat and Maize grains are made up of an embryo and endosperm, separated from each other by a flat plate, the scutellum; the embryo containing only **one cotyledon.**

In germination the Pea or Bean sends down a single main root on which lateral roots are developed, whereas the Maize and Wheat produce a number of independent fibrous roots spreading out in all directions.

The Pea and the Wheat may be taken as representing two types of plants which we shall have occasion to refer to in a subsequent chapter.

NOTE.—The elementary portions of the work outlined in this chapter should be begun in Class P, where the pupils could be taught to describe the general appearance of Bean and Pea seeds, and Maize grains. The next step would be to require the pupils to germinate these seeds in damp sawdust, and learn from observation the stages of germination and early growth. Every lesson in Nature-study should, as far as possible, be accompanied by drawing exercises. For instance, a drawing of the Bean seed should be made by the child on the slate and the position of the stalk-scar accurately marked. The seeds, as they begin to germinate and grow, should be taken up at intervals of a few days—the length of the intervals depending on the rate of growth—and drawn by the pupils on their slates. In this way the details of the history of the early life of a seedling could be worked out by the pupils themselves. In S. I the work could be carried a stage further; pupils might here be expected to ascertain and describe the difference in structure between the Bean seed and Maize grain, and to note the similarity of structure of the former to the Pea seed and of the latter to the Wheat grain. At this stage, too, the meaning of a "starch test" might be taught, when pupils could be led to discover the presence of starch in each type of seed. Special attention should be drawn to the system of roots each type gives rise to.

The root-system in each case should have special attention bestowed upon it, and the two types of seed should be contrasted and compared.

In S. II Vegetable-marrow, Pumpkin, Kidney-bean, and other seeds might be similarly investigated and the use of the stored-up food supply discovered. If necessary, additional lessons could be given to S. III and higher classes by expanding the work already done.

III.—LEAVES.—Part 1.

Parts of a Leaf. Take any ordinary leaf and make out the following parts—**stalk, blade, mid-rib, ribs, veins, margin, surface, axil** (angle between attachment of leaf and stem, in which bud is produced).

Use of Mid-rib, Ribs, and Veins. It will be seen in fig. 7 as also in the leaf under examination, that the mid-rib is really a continuation of the leaf stalk, and runs from the base to the apex of the leaf. Branching out from the mid-rib are the ribs, and running between and joining up these are the veins. The mid-rib, ribs, and veins are in fact the stiff parts of the leaf, and, acting like the ribs of an umbrella, keep its surfaces stretched out and so exposed to the light and air. By placing the cut stem of a leafy branch in water coloured with eosin it will be seen that the colouring matter in a short time has found its way into the mid-ribs, and through the ribs and veins into the softer part of the leaves. From this we learn that, in addition to acting as supports to the leaves, the mid-rib and ribs form a complete system of channels by

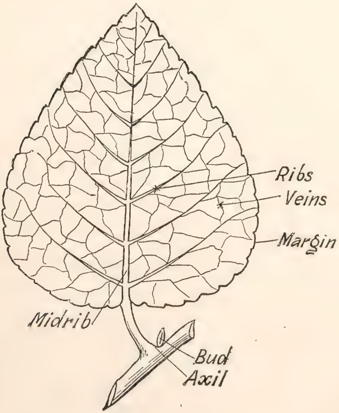

Fig. 7.—Lime leaf.

means of which the food absorbed by the root is distributed through the softer parts of the leaf. The starch and other food-materials formed in the leaf are moreover drained off by other passages which are bound up with these channels.

Colour of Leaves. In general the colour of the leaf is green, though the shade may vary considerably, and the under surface is much lighter in colour than the upper.

The Leaf-Stalk. The leaf-stalk we have seen is that part of the leaf by which it is attached to the branch or stem. When the leaf is about to fall, a layer of cork forms at the junction of the stalk and branch; this layer then splits, the leaf falls to the ground, and the wound, instead of being raw, is sealed up with a waterproof covering. The stalk varies considerably in length—it may be long, of medium length, short, or entirely absent.

Examples illustrative of the foregoing are readily obtained.

THE BLADE.

Shape of Blade. If a typical leaf-blade be carefully divided down the centre of the mid-rib, it will be found to consist of two equal and similar portions. There are however a good number of exceptions to this normal type, well seen in leaves of Begonia, Blue-gum, *Elatostemma Rugosum* found plentifully in most situations in the bush, and in many of the leaves of the Poro-poro, *Solanum Aviculare.* In shape the blade varies considerably: in the Pine and Larch it is needle-shaped; in the Pansy it is egg-shaped; in the Convolvulus it is arrow-shaped; and in the garden Nasturtium it is circular. Examples of other shapes can easily be procured.

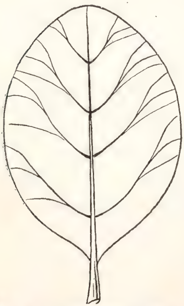

Fig. 8.—Quince leaf, showing whole or entire margin.

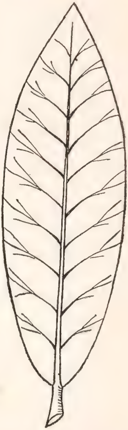

Fig. 9.—Rhododendron leaf (entire margin).

The Margin. The margin may be whole or entire, as in the Rhododendron or Quince, or it may be cut into. The incisions moreover may be such as to separate the blade into a number of divisions sometimes called lobes —the Plane leaf has five well-marked lobes, and each of these lobes may be further subdivided. The marginal indentations moreover may be such as to produce projections like the teeth of a saw, when the margin is said to be **serrate**; or like an animal's tooth, when it is called **dentate**; or the projections may be rounded, forming a **crenate** margin. For instance, the margins of the leaves of the Spanish Chestnut and Rewa-rewa are serrate, of the

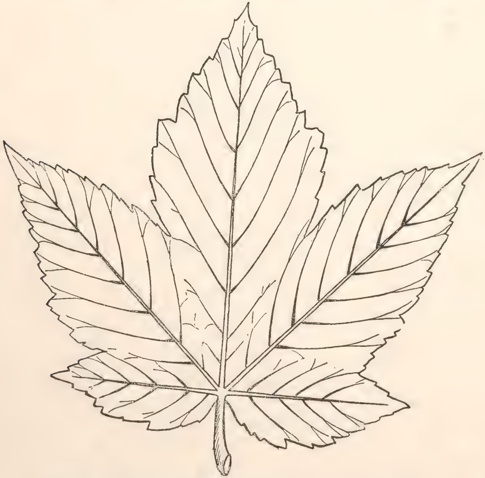

Fig. 10.—Plane leaf showing palmate venation and five-fold division of blade.

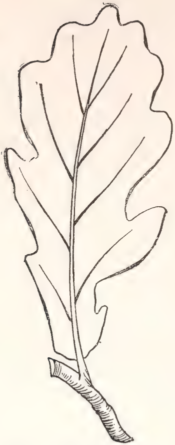

Fig. 11.—Oak leaf, incision in margin moderately deep.

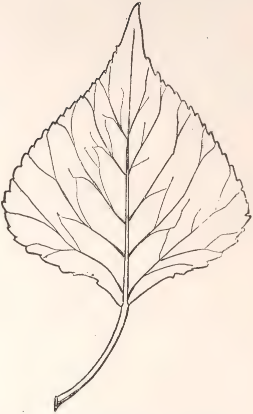

Fig. 12.—Poplar leaf, showing crenate margin.

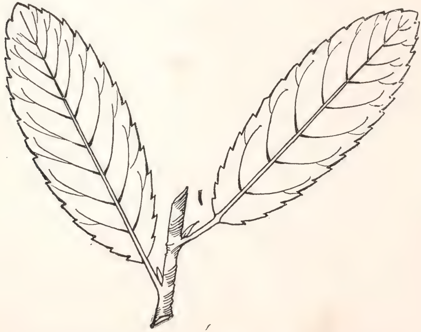

Fig. 13.—Laurel leaves, with finely toothed margin and buds in axils

Mako-mako dentate, and of the Poplar and Mahoe crenate. The terms saw-like, toothed, rounded, may be used instead of the ones given above.

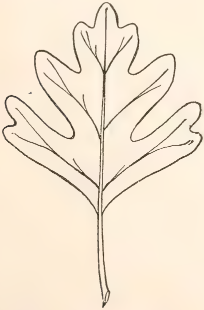

Fig. 14.—White Thorn leaf; incisions in margin deeper than in Oak leaf.

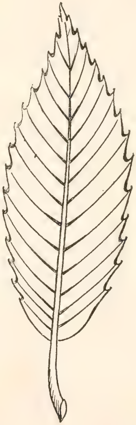

Fig. 15.—Spanish Chestnut, (serrate margin).

The Surface. The surface of the blade may be smooth, rough, glossy, dull, hairy, furnished with spines or prickles, wrinkled, or sticky.

Venation of the Blade. The arrangement of the veins may be grouped under two heads (1) **parallel veining**, (2) **net-like veining**. In parallel-veined leaves, a number of veins nearly equal in size extend side by side from the base toward the tip of the blade. The veins are approximately parallel, and are united by smaller ones running across nearly at right angles. Parallel veining is characteristic of grasses and lilies.

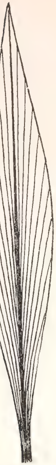

Fig. 16.—Grass blade showing parallel venation.

Pinnate and Palmate Veining. There are two subdivisions of net-like venation: (1) pinnate venation, (2) palmate venation. A blade with pinnate (feather-like) venation has a number of ribs or veins starting from the mid-rib at different levels and running to the margin. These are arranged something like the pinnae of a feather, hence the name pinnate (fig. 15). A palmately veined leaf has several large veins which radiate from the lower part of the blade towards its margin (fig. 10).

Texture. This may be tough or leathery, easily torn, thin, thick and juicy, dry, opaque or more or less transparent.

NOTE.—A great deal of useful work could be done under the heading of leaves in the Infant Department. Pupils will first of all learn to recognise and name the parts of a leaf, *e.g.*, the leaf-stalk, blade, surface, margin or edge, mid-rib, veins, etc. Rough slate drawings will help to impress this part of the work, which should be continued until the pupils are able to recognise and name with readiness from actual specimens the parts of a leaf. A child, for instance, on being handed a specimen should be able without hesitation to stand up, point to, and name the different parts—"this is the stalk, this is the blade, here is the mid-rib, and here the margin" etc, etc. Each child should also be able to describe the position of each part—*e.g.*, "This is the mid-rib, running through the centre of the blade." "The margin I am touching is the edge of the blade." "This is the blade, it grows at the top of the leaf-stalk," etc., etc.

Having mastered these preliminary details, and noted the difference in colour between the upper and lower surfaces, the various parts might be still further studied, the length of the leaf-stalk, the shape of blade, the incisions in the margin, the surface and the venation. All this must be very simply treated at first, though pupils in the upper divisions of the Infant Department might reasonably be expected to describe from actual specimens the appearance of simple leaves, *e.g.*, the leaf of a plane tree would be described in some such way as the following—"This leaf has a pretty long leaf-stalk, and a wide blade; its surface is smooth; the lower surface is lighter in colour than the upper one. The blade is divided into five parts, each of which ends in a point; a large vein starting from the upper part of the leaf-stalk runs to the point of each division; the veins stand out further from the under surface than from the upper surface. The margin of each of the five divisions has in it a number of deep cuts," etc., etc. The accuracy of description, the terminology, and the amount of detail required will depend entirely on the progress of the class.

In all these lessons pupils should be encouraged to bring specimens, but not in an aimless way. For instance, after a lesson on leaf margins, the leaves to be brought would be those having a special bearing on this part of the subject only. If there is time, the contributions should in all cases have a few words bestowed on them; the contributors might be asked where they obtained the leaves, the name of the plant, where it grew, etc., etc.

Almost any New Zealand bush will furnish examples of the types of leaves referred to.

The simpler forms should in all cases be drawn by the pupils on slates, special attention being paid to proportion and detail. The pupils, moreover, should be encouraged to press and dry the leaves between sheets of paper; much useful material which would always be available for reference could in this way be collected.

IV.—LEAVES—PART 2.

Division of the Blade—Simple and Compound Leaves. The margin of the blade, as we have seen, may be entire, or may be cut into by incisions. These, often of considerable depth, tend to modify the form of the blade, and split it up into a number of lobes. The depth and shape of the sub-divisions vary a good deal. For instance, the incisions in the Oak are shallow, in the Hawthorn somewhat deeper, and in the Buttercup extend almost to the mid-rib. So long as this is not reached, the leaves are said to be **simple** (figs. 11–14). When, however, the blade is split up by incisions which reach the mid-rib, and is in consequence divided into a number of leaflets, the leaf is said to be **compound** (figs. 17 and 18).

Types of Compound Leaves. The two subdivisions of net-like veins give rise to two distinct types of compound leaves—(i.) **Pinnately compound leaves** ; (ii.) **Palmately compound leaves.**

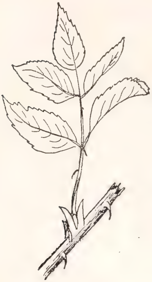

Fig. 17.—Compound leaf of a Rose.

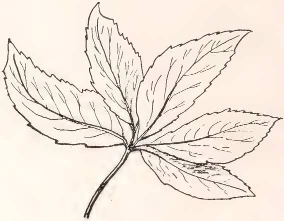

Fig. 18.—Palm-like leaf of a Virginia creeper.

These types are very common in the New Zealand bush ; the Towai and Titoki will furnish examples of (i.) and the Puriri and several species of *Panax* of (ii.).

In the former, the leaflets are arranged in pairs along the mid-rib, each pair springing from approximately the same level (fig. 17). In the latter the leaflets, varying in number, start from the upper end of the stalk, or from what, in a palmately-veined simple leaf, would be the base of the margin (fig. 18).

How to distinguish Compound Leaves. A compound leaf consists of a number of separate leaflets attached to a common stalk. Why, it may be asked, do we not call it a branch, and speak of the leaflets as leaves? A number of reasons may be given to show that a compound leaf is not a branch, but a single leaf. A knowledge of these, moreover, will enable us to determine whether a leaf is simple or compound.

In the first place, if the leaf-stalk of a compound leaf were a branch, it would arise in the axil of a leaf—but this it does not do—on the contrary, **it has a bud in its axil.** Then, again, if the leaflets were true leaves, we would expect to find buds in their axils, but these do not occur in this position. Finally, a branch terminates, not in a leaf, but in a bud; hence, if we find a stalk bearing a terminal leaflet, we may conclude that the stalk with its leaflets is not a branch. An examination of a few compound leaves will make this absolutely clear to a class.

Monocotyledons and Dicotyledons. If a Pea seed and a grain of Wheat be caused to germinate, the former we have seen will be found to possess two seed-leaves, and the latter only one. Experiments with a number of other seeds will show that in all cases germination results in the production of either one or two seed leaves. From this it will be seen that plants readily fall into two classes—those having one seed-leaf, such as Wheat, Maize, etc.; and those having two seed-leaves, like the Pea, Bean, Turnip, etc. The former are called **monocotyledons,** and the latter **dicotyledons.**

Further differences will easily be noticed. *e.g.*, That the roots of monocotyledons consist of a number of independent fibres spreading out in all directions, and that their branches bear parallel-veined leaves; on the other hand, that a dicotyledonous plant sends down a single main root, from which spring smaller lateral roots, and bears on its branches net-neined leaves.

By comparing and contrasting the seeds of these two types, points of resemblance as well as of difference will be noticed. A description of these seeds has already been given.

V.—SPINES, THORNS, AND PRICKLES.

Stem-spines. Examine a Hawthorn shoot; it is covered at intervals with sharp pointed woody outgrowths called thorns. Many of these stand in the axils of leaves, and themselves bear small leaves. But we have learnt that a branch always has its origin in a leaf-axil—moreover, that leaves are always borne by branches—hence we conclude that these thorns represent **stems** or branches, modified to act as a protection for the plant.

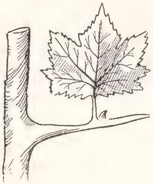

Fig. 19.—Stem spine of Hawthorn, bearing leaf.

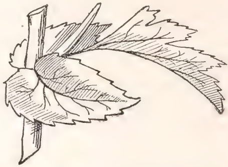

Fig. 20.—Stem spine springing from axil of leaf.

Leaf-spines. The leaves of the Holly and the Thistle have hard spinose outgrowths which are clearly portions of the blade or **leaf-spines.**

In the Barberry the spines are branched, and give rise in their axils to branches. Moreover, on the Barberry tree the whole of the transition stages between the leaves and spines can be traced. The spines of the barberry are modified leaves.

In the common Furze, or Gorse, some of the thorns possess axilliary buds, and hence may be regarded as modified leaves; whilst others are found on the ends of the stems. The stem, we have seen, never ends in a leaf, but in a bud which develops into a shoot; hence when we find the stem terminating in a spine, we may regard the spine as a modified branch. Thus, in this plant, both leaves and branches have been modified to form spines.

Prickles, or Outgrowths of the Bark. The leaves and stems of Brambles and Roses have prickles or woody hooks growing out of them—well seen in the Blackberry and Bush-lawyer. These occur on the plant without any definite plan of arrangement. They do not arise in the axils of leaves, nor do leaves arise in their axils; they are, moreover, attached to the bark only, and may be easily torn off. For these reasons we may conclude that they are merely out-growths of the bark.

It will be noticed that the so-called thorns on Roses and Brambles are wedge-like in shape, with a narrow elongated base, and grow on the stem in such a position that they are easily removed if pressed sideways, but offer considerable resistance to a force applied in the direction of their greatest length. Since the opposing force of the support acts in this direction, the importance of their position and arrangement is at once manifest.

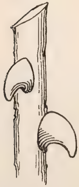
Fig. 21.
Prickles on stem of Bramble.

Plants armed for Defence. The green leaves and the fruit of plants furnish food for animals—the attacks of which it is sometimes found necessary to check. The Rose and Blackberry have outgrowths of prickles or woody hooks along their branches; the White-thorn or Hawthorn, and the Furze, are covered with thorns, whilst the Holly and Thistle have sharp spines attached to their leaves. The leaves of other plants have an unpleasantly bitter taste, whilst others, again, are poisonous.

NOTE.—Some of the work in this chapter might be taken up in the Infant Department—most of it, however, will probably be deferred until Standard I. is reached. Portions of it, indeed, might furnish material for lessons in Standard II. or Standard III. After dealing with palmate and pinnate venation, and leading pupils to understand what a leaf-axil means—the transition from the simple to the compound leaf of each type should be carefully worked out by means of numerous specimens. Reasons should at first be given in all cases for calling a leaf compound. The same remarks apply here as those already made on the bringing and preserving of leaves by pupils.

An investigation of thorns, spines, and prickles, and the considerations involved thereby as to whether they represent leaves, stems, or subsidiary outgrowths, will provide most useful and interesting material for lessons in Standard II. and higher classes.

It must not be forgotten that all this teaching should aim at developing facility of verbal expression; that every lesson, in fact, should be a lesson in language. Pupils should be trained to oral description, in which an application of the knowledge already acquired should play an increasingly prominent part. For instance, in examining a Furze branch, a child should be required to state why he considers one of the thorns a modified leaf, and another a modified stem.

In dealing with the two types of plants, monocotyledons and dicotyledons, it will not be necessary at first to introduce these names—certainly not in the lower classes—though there is no reason why they should not be learnt and used by pupils in the higher standards. The comparison and contrast between the two types at this stage will provide material for a useful revision of work already done.

VI.—LEAF ARRANGEMENT.

Arrangement of Leaves on Stem. The level at which a leaf grows on a stem is called a **node**, and the distance between two consecutive nodes is known as an **internode.** In some stems two or more leaves are attached at the same level *i.e.* at the same node; the leaf-arrangement is thensaid to be **whorled**, and the group of leaves at each node is called a **whorl.** On other stems (*e.g.* Wallflower) there is only a single leaf at each node, when the arrangement is known as **spiral.**

Whorled Arrangement. The leaves, when they occur in whorls, are arranged round the stem in a very regular manner, the angular distance between each pair of adjacent leaves being the same. Thus if there are two leaves at a node, they will be found growing on opposite sides of the stem as in the Hange-hange (*Geniostoma Ligustrifolium*). When three leaves occur each one is separated from the next by one third of the circumference of the stem. If the whorl consist of four leaves, they are arranged like the four arms of a cross, a quarter of the circumference of the stem separating each pair.

The way in which the leaves are disposed at one node relatively to those at successive nodes either above or below is equally regular. In some cases they are immediately above each other, in which case there are as many longitudinal rows of leaves as there are leaves at each node, when the leaves are said to be **superposed.** Some of the common Ferns will furnish examples. In others each leaf in one whorl is immediately above a vacant space between two leaves in the next lower whorl, and the leaves of every alternate node stand exactly over each other, well seen in several species of Rata, *e.g.*, Pohutukawa and Climbing

Rata. In this case there will be just twice as many rows of leaves as there are leaves at each node.

Spiral Arrangement. When only one leaf is inserted at each node, the arrangement is said to be **spiral.** If a piece of cotton be fastened to a leaf on a twig of Hazel and be taken along the stem passing over the bases of successive leaves, it will be found to trace out a spiral path. In this case the leaves form rows just as they do when occurring in whorls. Moreover each leaf, though separated from the one immediately above or below by a variable distance along the stem, is placed in such a way that its angular distance round the stem from either of the others is the same. For instance, in the Mako-mako, each leaf is inserted on the side opposite to that on which the leaf at the next higher node is attached, so that a piece of cotton would have to wind half way round the stem in passing from any one leaf to the next and once round the stem before reaching the leaf vertically above the first. In this case the **divergence** of arrangement is one-half. In other cases we might have to travel one-third of the distance round the stem in going from one leaf tc the next, or of course once round the stem before reaching the leaf vertically above the first—one-third divergence seen in the Mahoe. It will readily be seen during the operation that a twig with a divergence of one-half will have two rows of leaves, and one with one-third divergence, three rows of leaves. Thus the denominator of the fraction indicates the number of rows of leaves. If a Wallflower or an Oak branch be operated on in the same way, the thread will wind twice round the stem before reaching a leaf vertically over the first and moreover will pass five leaves—two-fifths divergence. It will be noticed when the divergence is one-half that the thread, in travelling round the stem to a leaf vertically above the first, passes over two leaves ; when one-third, that it passes over three leaves ; when two-fifths, that it passes over five leaves; hence the numerator of the fraction denotes the number of times it is necessary to pass round the stem in travelling from one leaf to the next vertically above it, at the same time touching all the leaves between these two.

Importance of Leaf Arrangement. A little thought will convince the observer that the arrangement which we have been describing is admirably adapted for enabling the plant to obtain the maximum amount of light, which, as we have already seen, is a matter of the first importance to healthy and rapid growth. Not only are leaves arranged on the branches with this object, but the branches themselves grow in such a way as to aid the leaves in securing it, where leaves, as in the case of the Daisy or Primrose, all spring from nearly the same level, the base of the leaf is cut away where shut off from the light. If this were not so, one leaf would overlap the other and, preventing the passage of light, would render the shaded portions useless.

The Position of Branches. We have already seen that buds from which branches develop occur only in the axils of leaves — axillary buds; or at the end of growing shoots—terminal buds. Hence the ultimate arrangement of branches on a stem must depend to some extent on the position of the leaves. It will be found that this is the case; but, as all the buds do not develop, it frequently happens that the final arrangement of the branches is by no means regular. Still, although the positions of the leaves do not absolutely control the branch system, they have a good deal to do with it. We do not, for instance, find opposite branches on a tree whose leaves are arranged on the alternate system. If the branches are opposite, the leaf arrangement must have been opposite or whorled, for wherever we find a branch growing, there must at one time have been a leaf immediately below it—whether the leaf-scar is visible or not.

NOTE.—The suggestions contained in this chapter will furnish material for work in Standard III. and higher classes. The subject of leaf-arrangement is one involving a considerable amount of difficulty for children and should be confined to the investigation of very simple cases. The earlier lessons should aim at leading pupils to see that leaves and branches are arranged on plants in conformity with fixed plans, and that the methods of arrangement can be discovered by investigation. The more difficult cases—if dealt with at all—should be deferred until pupils have reached Standard V. and Standard VI.

The importance of leaf-arrangement will afford a good opportunity of helping pupils to realise how effectively Nature works to secure the objects she has in view.

VII.—HOW PLANTS FEED.

Plants obtain food from the ground through their roots, and from the air through their leaves. The food, which must be in a dissolved state, enters the root through the fibres and root-hairs and gradually passing up the stem finds its way to the leaves; here the water is evaporated from the surface of the leaves, and the mineral and other matter carried by the water is left behind. From the air the plant obtains a supply of carbon-dioxide, which enters the small openings or pores on the leaves, and which in the presence of sunlight is decomposed into carbon and oxygen—the oxygen being sent out into the air and the carbon being retained—the air, in fact, is the sole source from which plants draw their supplies of carbon. The food which has been brought up from the root and the carbon derived from the air are next manufactured by the leaves into the substances required by the plant—one of these being starch. These substances then pass back from the leaves into the stem, and are either used at once by the growing plants or are stored up in the stem, root, or leaves, for future use.

The food which finds its way up the stem consists chiefly of the elements, oxygen, hydrogen, nitrogen, phosphorus, and sulphur; and the combining of these elements into substances suitable for the nourishment and support of the plant is known as assimilation.

FOOD OBTAINED FROM THE SOIL.

Absorption of Food (water and inorganic salts) by the root-hairs.—The organs which absorb water are the roots. If water be supplied to the leaves and stem of a plant, and the soil at the same time be kept dry, the plant will gradually wither. This proves that the shoot is unable to absorb sufficient water.

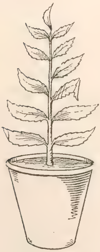

Fig. 22.

Fasten a piece of water-tight material over a pot, in which a plant is growing, in such a way as to prevent any water from entering the soil, and water the plant daily. It will be found, notwithstanding this treatment, that the plant will gradually wither.

It is not a difficult matter to show that the roots absorb water. Place a plant in a jar of water as shown. Insert a small tube through the cork, and by pressing the cork further into the jar, force the water up the small tube. If the air of the room be warm, the roots will rapidly absorb the water and the

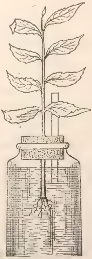

Fig. 23.

level in the jar will gradually sink. The small tube, will enable the diminution in volume to be seen by a class during the progress of a lesson. The water level in the tube at the beginningof the lesson should be marked by means of a small piece of white paper gummed round the tube.

Plant Food must be dissolved in Water.—

(*a*) If a plant be placed in water containing insoluble salts of all the chemical elements required by the plant it will be found that the roots will absorb the water, but that the salts will remain as a powder in the vessel, and in a short time the plant will cease to grow.

(*b*) If two plants be taken and one be placed so that its roots will dip into water holding eosin in solution, and those of the other into water containing red particles of carmine, which do not dissolve, it will be found that, whereas the red colour of the eosin has found its way into the roots and up the stem, the particles of carmine remain suspended in the water and no colour passes into the root.

Experiment *b* will also show—in the case of the eosin solution—that plant food dissolved in water enters the root and passes up through the stem and branches to the leaves.

Black ironsand found in such abundance round our coasts will provide an excellent insoluble substance for one of the experiments.

Path of Current up the Stem. The following experiment will show that the liquid passes up the woody part of the stem.

Place a branch bearing leaves in a vessel of water as shown, having previously cut a ring of bark from the stem. The bark should be cut right down to the wood, and, moreover, should be removed from that portion of the stem above the level of the water. In spite of the removal of the bark, the water will continue to travel up the stem and into the leaves, as is apparent from the fact that the leaves do not wither, but continue green and fresh. The base of the stem, in fact, continues to absorb water, which gradually passes up through the woody portion of the stem and finally into the leaves through the mid-rib and smaller nerves.

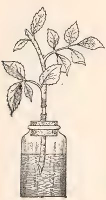

Fig. 24.

In the case of a soft stem, *e.g.*, that of a Sun-flower, which has no general woody body, but possesses bundles of woody tissue, the liquid passes up through these, which form the food channels.

The same results would be obtained by using a plant with roots instead of a branch as shown.

Transpiration. The passing away of water in the form of vapour from those parts of the plants which are exposed to the air is known as transpiration.

That water does pass away from the plant can be demonstrated by the following experiments:—

(*a*) Take a potted plant and carefully cover with a piece of tinfoil the earth in the pot, in such a way as to prevent, or at least minimise, the evaporation of water from the soil. Carefully weigh the pot and its contents, and after the lapse of an hour or two weigh again. It will be found that the weight has decreased ; for the soil has lost water by transpiration through the leaves of the plant. The decrease in weight does not represent the whole amount of water transpired, for the plant has gained slightly in weight owing to the carbon obtained from the carbon-dioxide in air. But the gain of weight in consequence of the absorbed carbon is so small in comparison with the loss brought about by transpiration as to be inappreciable, and may be neglected. Hence the difference in weight may be taken as representing the loss by transpiration.

(*b*) Place a stem bearing leaves in a jar of water as shown, fixing the stem firmly in the cork and allowing the cut end to enter the water. The cork must fit well and the hole through which the stem passes must be made water-tight to prevent the passage of vapour from the water in the jar. This can be done by pouring a little melted grease round the hole, after the stem has been inserted.

In the centre of a piece of cardboard of the necessary size cut a hole so that the cardboard will pass over the neck and rest on the shoulder of the jar. This will support a tumbler as shown in fig. 25, which must have its rim well-greased to make a vapour-tight joint. When this arrangement is placed in the sunlight, drops of water soon collect on the inner surface of the inverted tumbler, showing that water must have been given off in the form of vapour from the leaves.

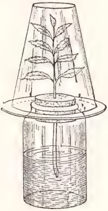

Fig. 25

Uses of Transpiration. The amount of plant food held in solution in the water which passes into the roots is very small; hence it becomes necessary for the plant to absorb a relatively large amount of water, in order to obtain a supply of food sufficient to support its growth. When the water has travelled up to the factories of the plant—the leaves—and has done its work of carrying up the salt solutions, it is got rid of to make room for fresh supplies. That is, transpiration enables the plant to obtain weak salt solutions in sufficient quantity to furnish the necessary supplies of food.

Then again, transpiration helps to draw the water containing the dissolved plant food up the stem, and tends to make the roots absorb liquids more quickly.

A simple experiment will illustrate this. Take a small thistle funnel and tie over the wider end, or mouth, a piece of dialysis paper. The paper should be soaked in water for some time previously and must be tightly tied over the funnel. Pour into the small end of the funnel some syrup or brine, and dip the large end into a basin of clear water. In a short time it will be seen that the liquid is rising in the tube. On tasting the water in the vessel it will be found that some of the sugar or salt has come through the membrane. This property of liquids separated by a membrane to pass into each other is known as **diffusion**. It will be noticed that both liquids have diffused through the membrane; but that the thinner liquid has diffused more rapidly than the thicker one. A plant is wholly made up of little cells or chambers, separated from each other by thin walls through which liquids are able to pass. The liquid in the small root hairs is denser than the water outside, and so the latter diffuses into the former, and with it the plant food held in solution. The water which enters these cells is less dense than that contained in neighbouring cells, so that some of it passes up into these, and so on into cells higher and higher up the plant. As the

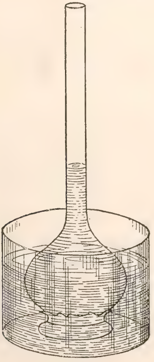

Fig. 26.

water is evaporated from the leaves, the liquid remaining in the leaf-cells becomes thicker than before, and hence thicker than that in the neighbouring cells. The denser liquid in the outer leaf-cells draws the thinner liquid from the inner cells ; and these from cells further back, and so the process of diffusion gradually extends through the branches and stem to the roots. It is in fact, partly owing to transpiration that the force is developed which brings up water from the soil.

Rate of Transpiration. The rate at which a plant transpires varies with the temperature; the warmer and drier the air is, the more rapid is the transpiration. These facts explain various familiar phenomena. On a warm day the leaves of many plants, *e.g.*, those of the potato and pumpkin, are often noticed to hang down and droop. This is because the water carried away by transpiration is in excess of that absorbed by the roots. Towards evening as the atmosphere becomes cooler, the rate of transpiration is checked and the leaves return to their normal condition. Again, if we place cut flowers in a box and exclude the light, they will remain fresh for a much longer time than if exposed to the air. Inside the box transpiration is slower because the air quickly becomes moist owing to the absence of light.

Plants Transpire chiefly through their Leaves. This can be readily shown by comparing the rate at which two branches transpire, one having many and the other having few leaves. If the comparison be made by carefully weighing the subjects of the experiment as detailed on page 28, it will be found that more moisture has passed through the plant having the greater number of leaves. Again, if the leaves be entirely removed from a plant, transpiration is very greatly retarded, if not entirely stopped. From these experiments we conclude that the leaves, exposing as they do a large surface to the air, are the organs through which transpiration chiefly takes place. A green stem is responsible to some slight extent for transpiration—though this depends a good deal on the stem; a woody stem hardly transpires at all.

How Roots obtain Food from the Soil. In a previous experiment it was shown that the plant food must be in solution before it can be absorbed by the roots. The rootlets spread out in all directions dividing and subdividing in search of dissolved plant food. The soil is always moist below the surface, even when it appears quite dry, a thin film of moisture surrounds each particle of earth. The root hairs spreading out and inserting themselves between these particles become so closely applied to them that the soil water diffuses through their walls and passes up the main roots and through the stem as already explained.

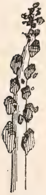

Fig. 27. Root hair with adhering particles of soil.

NOTE.—This portion of the work might be begun in St. I, or indeed earlier, if very simply treated. The first step is to lead pupils to see that a liquid can pass into the roots of plants and can be conveyed to the leaves—the next is to show that solid matter must be dissolved before it can be absorbed—from which it follows that available plant-food must be in a liquid condition. So soon as these primary facts have been grasped, pupils will be able to understand the meaning of transpiration—how it is brought about and its uses.

The path of the salt-solutions up the stem may or may not be taken at this stage—indeed, it might with advantage be deferred until dealing with the path of leaf-made food—when the entire movements of solutions and assimilated materials could be worked out; this, however, must be decided by the teacher. If it (the path of salt-solutions up the stem) be taken in St. I, it may require to be done again in the higher classes.

The uses of transpiration, the rate of transpiration, and the process of osmosis or diffusion should certainly be deferred until later on in school life, *i.e.*, should not be dealt with until St. III or higher standards be reached.

VIII.—FOOD OBTAINED FROM THE AIR. WORK OF LEAVES.

Absorption of Carbon-dioxide (CO_2). A description of the composition of air is given on the appendix page.

Plants absorb carbon-dioxide through their leaves. Fit a leaf into an air-tight cork through which a small piece of bent glass tubing is inserted as shown, and allow the end of the leaf-stalk to dip into the water in the jar. Applying the lips to the tubing suck out the air over the water—immediately bubbles of air are seen to come from the cut end of the leaf-stalk and rise through the water. We can continue this experiment for some time and so prove that the air which bubbles from the leaf stalk is not merely air imprisoned in the leaf, but has come from the surrounding atmosphere. When the air is drawn out through the tube, the pressure inside the jar and hence on the leaf-stalk is so reduced that the ordinary atmospheric pressure on the blade is able to force the air into the leaf and through the tissues until it reaches the cut surface.

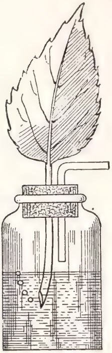
Fig. 28.

Each surface of a leaf is covered with a thin transparent skin. On the upper surface of most plants this skin is made up of closely fitting cells—whilst on the lower surface it is perforated by an immense number of minute openings or pores called **stomata**. It is through these pores that the carbon dioxide of the air enters.

The last experiment merely proves that air is able to enter the plant through its leaves. We have yet to show that this air contains carbon-dioxide. This can be done as follows :— Obtain a beaker of lime-water and breathe into it through a piece of fine glass tubing. The water quickly becomes milky in appearance owing to the presence of carbonate of lime. The air expired from the lungs contains carbon-dioxide and the union of this with the lime held in solution forms the insoluble salt carbonate of lime. This shews the presence of carbon-dioxide in air expired by breathing animals and as the number of such animals is so enormous, we may reasonably infer that the atmosphere contains an appreciable amount of the gas. Further proof will be obtained by exposing to the air some lime-water in a saucer. At the end of a few hours

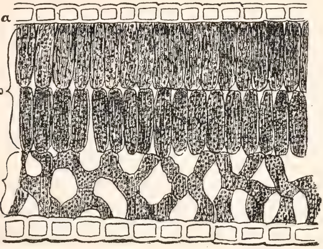

Fig. 29.—The inside of a leaf. Below the upper skin *a*, are cells of living green stuff *b*. Beneath these is the spongy part *c*, where the surplus water evaporates. In the lower skin *d* are many breathing pores. These are shown in Fig. 30.

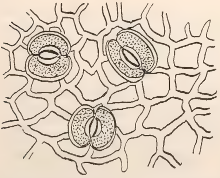

Fig. 30.—The lower skin of a leaf showing three breathing-pores.

a thin film of carbonate of lime will begin to cover the surface of the liquid. In this case the carbon-dioxide combining with the lime was supplied *by the air*. The following considerations will help to reinforce what these experiments teach.

In making culture solutions which we shall have occasion to refer to further on, it is unnecessary to include the element carbon. These culture solutions consist of mineral salts which replace the food a plant ordinarily obtains from the soil, so that evidently a plant does not rely on the soil for its supply of carbon. We know, however, that carbon in the form of carbon-dioxide exists in the air, and we have seen moreover that the air is able to enter the plant through its leaves ; it seems a reasonable inference that the air supplies the plant with carbon. An experiment will enable us to confirm this surmise.

One of the compounds containing carbon which are formed by plants is starch, and starch is easily recognised; for it gives a characteristic blue colour when treated with a solution of iodine (see page 3). Take a green leaf which has been exposed to sunlight and boil it for a few minutes in water, next immerse it in alcohol for a short time and its green colouring matter will be dissolved out. Having washed it well in water to remove all traces of the green solution, place it in a weak solution of iodine (in which a small quantity of potassium iodide has been dissolved) and at once the bleached leaf will assume a blue or purplish brown colour showing the presence of starch. This shows that carbon has entered the leaf when it is exposed to ordinary air.

We have yet to show that a leaf, if exposed to air from which the carbon-dioxide has been withdrawn, cannot form starch—that it is unable to obtain the necessary carbon. The following experiment will make this clear. Fit up a jar as shown—placing in it a small pot-plant and a glass vessel containing caustic soda. This substance will rapidly absorb any carbon-dioxide there may be inside the jar. Insert through the cork, which must be air-tight, a bent glass tube having the bend filled with pieces of caustic soda so as to absorb any carbon-dioxide which would otherwise find its way inside the jar. The pot-plant must previous to the experiment be kept in the dark for twenty-four hours to free it from starch. If now the whole be exposed to sunlight for a few hours, it will be found that no starch has been formed. By this and other experiments it can be proved that green plants obtain the whole of their carbon from the carbon-dioxide of the air, and—as we shall subsequently show—that sunlight is necessary for the process.

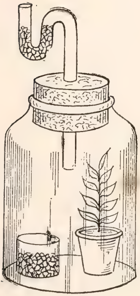

Fig. 31.

Decomposition of Carbon-dioxide by Leaves, in the presence of Sunlight. When the leaves of a plant are spread out to the air, carbon-dioxide is absorbed by them, and in the presence of sun light is decomposed or split up into its two parts, carbon and oxygen; the carbon unites with other plant food to form starch &c., and the oxygen is returned to the air.

Take a bunch of any green water weed—watercress does admirably—and put it in a vessel of water. Cover the leaves with an inverted funnel in such a way that the

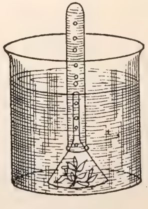

Fig 32.

smaller end of the funnel is below the surface of the water. Having filled a narrow test-tube with water, invert it over the neck of the funnel; when in position the test-tube should be completely filled with water. If this arrangement be exposed to sunlight, bubbles of gas will be given off by the plant and will collect in the tube. When a sufficient quantity of this gas has been collected, the test-tube can be removed and the gas tested. Be careful to close the test-tube with the thumb before raising it from the water. A glowing splinter plunged into the test-tube will at once burst into flame showing that the gas is oxygen.

If now the experiment be repeated in the dark, or without using any plant, no gas will be given off. From this we learn

(*a*) That the green leaves of plants are able to decompose carbon-dioxide;

(*b*) That sunlight is necessary for the process.

The immense quantity of carbon-dioxide continually being poured into the air as the product of respiration and combustion, as also from the decomposition of organic matter, and from other sources, is thus to a large extent withdrawn. The leaves decompose the carbon-dioxide, returning the oxygen to the air, which in this way is rendered suitable for the support of life.

NOTE.—Owing to the small amount of carbon-dioxide held in solution in ordinary water, it is sometimes difficult to collect a sufficient quantity of oxygen to test its properties. It will be found a good plan before making the experiment to empty a bottle of soda-water into the water in the vessel. When this is done the whole should be stirred about or shaken up for a few minutes before fixing the apparatus—in order to remove any of the carbon-dioxide which is likely to be liberated during the progress of the experiment.

Formation of Starch in Leaves exposed to Sunlight. We have already seen that green leaves are able to absorb carbon-dioxide and form starch. This process can take place only in the presence of sunlight. The following experiment will verify this statement.

Take a nasturtium or a sunflower leaf, pin a couple of pieces of cork on either side of it as shown, and expose it to sunlight for some time. Remove the green colouring matter by first killing the leaf in boiling water and then placing it in methylated spirits, and test with iodine solution. It will be found that the part from which the light has been excluded remains bleached—whereas the rest of the leaf becomes bluish owing to the presence of starch.

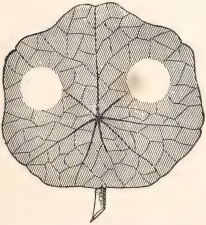

Fig. 33.—Nasturtium leaf with discs of cork attached.

If the experiment is to be performed quickly—the plant should be kept in darkness for some days previous to being operated on. Otherwise the cork must be left on the plant for a few days before the starch test is applied. Tinfoil may be used instead of cork for covering up the whole or a portion of the leaf. Again, if a plant with variegated leaves be treated in the same way—we shall find that only in those parts which were originally green can starch be detected. The parts which were white will show no indication of starch. This is a further illustration of the fact that only the green parts of plants absorb carbon-dioxide and by its aid build up starch.

How Plants grow towards the Light. That light is necessary for the growth of plants can be further illustrated by raising a small quantity of, say, mustard, in a box until it is a few inches above the soil. If the box be now covered so as to shut off the light and a small hole be made in the side—the plants will bend over towards the opening.

Summary of Lessons on Leaves. The work already done under this heading might be collected and summarised as follows—shape of leaf—colour—simple and compound leaves—position—function.

NOTE.—It will probably be found necessary to reserve the work outlined in this chapter for Standard II. and higher classes. Pupils should be brought to realise that air is able to enter the plant through its leaves—and that since air contains carbon-dioxide, which the leaves are able to decompose, and moreover since the leaves in order to form starch (of which carbon is a necessary ingredient) must be supplied with air containing carbon-dioxide, it seems a reasonable inference that the air supplies the plant with carbon. The final proof of this fact is furnished by growing plants in culture solutions which do not contain carbon.

The work here should not be hurried. The special teaching of every experiment should be clearly understood, and the bearing which each link has on the whole chain of experiments should be fully grasped—all this will require time. The work begun in Standard I. and Standard II. should be gradually extended in the higher classes, and revised in such a way as to show the connection between each successive step and those already taken.

It is unnecessary to add that as much of this work as possible should be done by the pupils themselves. When conditions render this difficult, if not impossible, some of the pupils should be required to share in the work of the experiments—which ought to be carried out on such a scale that the whole class can follow and understand what is being done.

IX.—PATH OF LEAF-MADE FOOD DOWN THE STEM.—CULTURE SOLUTIONS.

Path of Leaf-made Food down the Stem. We have seen that the salt solutions obtained from the ground pass up to the leaves, and that the channels through which these are conveyed lie in the woody part of the stem. In the leaves we have learnt that the food obtained from the ground and that derived from the air are manufactured into various organic compounds, one of which is starch. The food made in the leaves passes down the stem, and is either used up in nourishing the growing parts or is stored away for future use. Take a leafy branch and peel the bark completely off the lower portion for a couple of inches from the end. The soft tissues lying between the bark and the wood must also be removed. Place the twig in water so as to immerse it for a few inches above the ringed part. After a time the twig will begin to send out rootlets *above* the cut. If any appear on the ringed part they will be small and few in number.

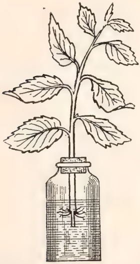

Fig. 34.—Twig from which ring of bark has been removed.

Place a similar twig in water in the same way without removing any of the bark, and notice that the roots are produced at the end.

From these experiments we learn that the food *from* the leaves finds its way through the soft tissue between the bark and the wood known as the **bast.**

How Starch is conveyed through the Plant. The materials which are drained off from the leaves must be in solution.

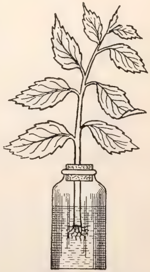

Fig. 35.—Twig immersed without removing any of the bark.

Starch is an insoluble substance, and so cannot pass through the cell walls. It therefore changes into a soluble sugar before being conveyed away, and on reaching its destination may remain as sugar, as in the beet-root, or be changed again into starch, as in the potato tuber. In connection with this explanation simple experiments should be made shewing—

(a) The insolubility of starch ;
(b) The solubility of sugar ;
(c) The presence of starch in the potato tuber ;
(d) The presence of sugar in the beet-root.

Culture Solutions. The food of plants consists of the following substances *(a)* organic : oxygen, hydrogen, nitrogen, carbon ; *(b)* inorganic : potash, magnesia, lime, phosphoric acid, sulphuric acid, iron, silica, soda, chlorine. Of these the whole of the organic substances and the first six of the inorganic substances are essential ; plants cannot grow without them. The last three, though not essential, are found in many plants.

If the plant be supplied with those substances which are essential, it will grow and thrive ; if these be withheld from it, it will die. Interesting experiments can be made by growing plants in water or sand to which plant food has been supplied, these substances in themselves containing little or no available plant food.

In each of two pots filled with sand, place a few bean or pea-seeds. Moisten these every few days, the one with pure water, and the other with a small quantity of some culture solution. The seeds in the pot on which the water is poured, will germinate and continue to grow until the supply of food contained in the cotyledons is exhausted, and may reach eight or nine inches above the edge of the pot. Those in the other pot supplied with all the essential substances will grow into large plants, and if the conditions be favourable, may bear flowers and fruit.

The following culture solutions—either of which may be used with success—do not contain the element carbon. It is this fact, taken in connection with what we have already learnt, which clearly shows that the necessary carbon is obtained from the carbon-dioxide of the air.

(A)	Potassic nitrate ...	1 Gram.
	Calcic sulphate ...	½ ,,
	Magnesic sulphate ...	½ ,,
	Calcic phosphate ...	½ ,,
	Sodic chloride ...	½ ,,
	Ferrous sulphate ...	A trace
	Water	1 litre
(B)	Potassic nitrate ...	2 Grams
	Calcic phosphate ...	1 Gram
	Magnesic sulphate ...	1 ,,
	Ferric chloride ...	A trace
	Water	2 litres

NOTE.—None of the work in this chapter should be attempted below Standard III.; most of it will probably be taken up in the higher classes. All the experiments—which will take a long time to work out—should be undertaken by the pupils themselves. That is, the pupils should fix up the necessary apparatus, and should give special attention to dates and to detailed descriptions of what they have done, observed, and learnt.

In the case of the cultivation of plants in artificial soils and in solutions, quite a good deal of investigation could be carried out in the direction of determining the inorganic substances essential for growth. Both water and sand or some substance of the kind, should be used in this connection.

X.—CONDITIONS ESSENTIAL TO GROWTH.

(1) **The plant or seed must be living**; it is impossible to induce a dead plant of any kind to grow. If a dead pea or bean seed be placed in damp sawdust or moist ground,

it will swell up as a living seed would, but it will not send out a stem and root; in other words it will not grow.

(2) **A supply of water is necessary.** If a few seeds are placed in dry flannel—and some others in moist flannel —the former will remain unchanged whilst the latter will swell up, burst, and begin to sprout. Water is required because *(a)* it forms part of the living substance of the plant; *(b)* it is a food substance, it is in fact plant-food; *(c)* it is the vehicle by means of which the food-stuffs are carried to the growing parts; *(d)* it keeps the soft green parts stiff and extended, a condition essential to growth. (This was referred to on page 29, dealing with transpiration).

(3) **Free oxygen is required.** If the air is freed from oxygen, growth becomes impossible. To show that this is so, take two bottles, with closely fitting corks, and from the under surface of each cork (which must be air-tight) suspend a small piece of sponge in the pores of which some seed such as cress is sown. Before suspending the sponges, pour a little water into one of the bottles, and some pyrogallic acid into the other. In the sponge which hangs over the water the seedlings quickly begin to germinate. In that suspended over the pyrogallic acid, no germination takes place, for the acid has withdrawn all the oxygen from the air and so prevented growth. We can now understand why plants sometimes die in very moist ground. The soil becomes so saturated with moisture, that the air is driven out, and the roots deprived of oxygen actually die of suffocation.

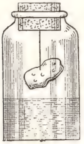

Fig. 36.—Sponge with cress seed in pores suspended over pyrogallic acid.

(4) **The temperature must be suitable.** Experiments will readily suggest themselves to show that seeds or plants exposed to extremes of temperature will not grow.

(5) **There must be a sufficient and suitable supply of food-material.** This does not mean that there must be food-stuff available outside the growing plant or seed; that may be already in the plant or seed itself stored up in reserve. If a bean seed is germinated, taken up out of the ground, and carefully dried, so that all the absorbed moisture is got rid of, it (the seed itself) will be found not to have increased in weight. The food-material stored up in the seed has merely been transferred from one part of the plant to the other.

Growth in Length. An interesting experiment to show what part of the root grows with most rapidity can be carried out as follows:

Take a pea seed which has begun to grow, and mark on it with Indian ink a number of lines at equal distances apart. Suspend the seed in a jar over some water. The water will keep the air moist and so promote more rapid growth. If the plant be examined at the end of a couple of days, it will be found that the distance between the marks is practically the same except near the tip of the root. Here the consecutive marks are now separated by a longer interval showing that growth has been most rapid at the apex of the root. Nearer the seed itself the radicle has hardly increased in length at all.

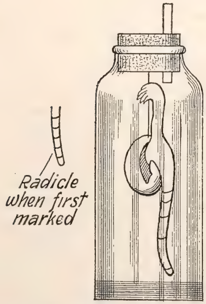

Fig. 37.—Pea-plant suspended in jar over water, showing elongation of the radicle.

The stem can be experimented on in a similar way.

NOTE.—The work set forth in this chapter might be begun in Class P., and continued throughout the standard classes. Even the youngest child taking up a course of Nature Study can realise that in order to grow, a seed must be living. The necessity for supplying moisture too, is easily demonstrated, though many of the reasons why water is required, are quite beyond the comprehension of the average child in the lower standards. Growth in length might be investigated in almost any of the classes—though great accuracy of measurement can hardly be expected from the younger pupils. As in other cases it will probably be found necessary in this connection in the upper standards to repeat in a more expanded and accurate form the work already begun in the lower classes.

XI.—STORAGE OF FOOD.

Storage in Roots. If the Pea or Wheat seed be planted it will—in favourable weather—come through the ground in a few days, and at the end of some weeks will have grown into a plant several feet in height. In course of time it will produce flowers which will gradually develop into the ripened fruit—the whole process of growth from the germination of the seed to the ripened fruit occupying at most a few months. Plants which grow from seed, produce flowers, fruit, and seed in one year, and then die, are called **annuals.**

If on the other hand Carrot or Parsnip seed be sown, the plant after coming through the soil will throw up a tuft of leaves and proceed to form a long tap-root which will increase in size as the weeks pass. No flowers, and hence no seeds will appear ; if we wish to obtain seed we must leave the plant in the ground until next season, when it will send up a long flowering stem, on the ends of which the flowers and afterwards the seeds will be borne. If now the root be examined, we shall find that it has become stringy, fibrous, and probably hollow. The plant-food stored in the root has in fact been used up in nourishing the flower and seed. Such plants which flower in the second season of growth and then die, are called **biennials.** The production of flower and seed is a great strain on the plant, and it is to enable it to bear this effort that so much food is stored up.

During the process of ripening, there is a steady drain of nourishing material from the other parts of plant into the seed. For example, from the leaves and stem of a Wheat plant most of the nutritious material is carried away in solution, and deposited in the seed. A seed therefore is a reservoir of nourishment, and man cultivates cereal or grain crops in order that he may utilise this valuable store of food. It is unnecessary to mention these in detail: Wheat, Oats, Barley, Maize, etc., are well known, and will, if necessary, furnish excellent material for further lessons.

In the case of biennials, the plants rest between the two seasons of growth. A Carrot (*i.e.*, root of a carrot) for example, may be left in the ground during the winter, without injuring its power of producing seed the following spring. The cultivator grows root crops in order that he may interfere with this resting stage and utilise the food stored up by the plant.

Storage in Leaves. The roots are not the only places where plants form reservoirs of food. In the Cabbage for instance, the leaves act as the place of storage. If a head of cabbage be examined, it will be found to consist of a number of leaves growing on a thick stalk folded tightly together. The ones towards the top of the stalk are small, and occupy the inner portion of the head, whilst the leaves growing from the base of the head are large, and act as a cover enveloping and protecting those within. These, it will be noticed, removed from the light, are much whiter than the outer leaves. The Lettuce is another plant which utilises its leaves as a place of storage for food.

Storage in Stems. Then again we have already seen that a food supply is stored up by the Potato in its tubers, and by such plants as the Onion and Lily in their bulbs. In the case of the Dahlia, the tuberous bodies in which the food is stored arise on the base of the stem, and possess neither leaves nor buds, they are in fact true roots.

Summary of Lessons on Roots. The work already done might now be summarised, or a lesson might be given to a junior class on roots, when the following could be educed: (1) The root serves to hold the plant firmly in the ground. Pupils can readily be brought to see that the vertical position of plants requires them to be firmly set in the soil; with this object some roots spread themselves out far and wide, and penetrate to considerable depths. Reference can be made in this connection to large forest trees, and comparisons drawn between plants requiring a firm hold and those whose height above ground and weight do not cause any great strain on the root, such plants being easily removed from the soil.

(2) The root enables a plant to obtain a supply of food from the soil. This can be illustrated by some of the experiments already described, the precise nature of these depending on the intelligence of the pupils.

(3) The root serves as a storage place for food, *e.g.*, root of Carrot, Parsnip, Turnip.

The Shape and Colour of Roots. This will furnish subject matter for a useful lesson to a class of beginners. The pupils may be called on to describe the colour and shape of a few typical roots, and, at the close of the lesson, to draw the forms examined and described. The following would serve as a basis for such a lesson.

"The spherical or round root of the turnip; the cone-shaped root of the carrot; the long whip-like tap-root of the parsnip; the spindle-shaped root of the radish; the fibrous root of the wheat."

NOTE.—In this Chapter "storage of food" is placed before the "summary of lessons on roots." It does not follow from this that the former should precede the latter in the order of teaching. Simple lessons on roots might well be given in the Infant Department, where pupils could be taught to describe the colour, form, and general appearance of roots, and be led to realise how necessary it is that plants be held firmly in the ground with their stems vertical and leaves spread out to the air and sunshine. The storage of food should not be dealt with until the pupils have been led to see that under certain conditions a reserve of food is necessary. To talk to Infants about plants storing up food for future use would be mere waste of time, for they would not be sufficiently far advanced with the subject to understand what a food-supply meant, and why it was at any time necessary. In S. II. or S. III., where storage of food would probably be taken, the lessons might with advantage lead to a general summary on the functions of roots.

XII.—THE STEM.

We have seen how important to the plant are its leaves and roots; the former absorbing carbon-dioxide from the air and manufacturing plant food; and the latter obtaining from the ground the salt solutions from which the plant draws its supply of mineral matter. The whole of the food absorbed by the plant must find its way to the leaves, and the leaves themselves must be spread out to the air and sunshine, hence the necessity of the stem and branches. The duties of these members are (1) to bear leaves and spread them out; (2) to supply the leaves with the water and mineral substances taken in by the root, and necessary for their work; (3) to conduct to the rest of the plant the food materials prepared by the leaves. A stem, together with the leaves it bears, is called a **shoot.**

How Stems are thickened. The stems of many plants have to support an enormous weight of leaves and branches as well as to withstand the force of the wind. It is necessary therefore that they should grow thick and strong; the strengthening is usually brought about by the walls of the water vessels changing into wood.

In woody stems the growth takes place in a soft layer of material between the wood and the bark known as **cambium.** The production of new wood is most rapid in summer when the leaves are manufacturing plenty of food. As autumn approaches, the activity of growth becomes less, and wood of a closer texture is formed. In winter the process of growth is suspended; but with the warmth and moisture of spring bringing an abundant supply of food it is again renewed.

The difference in texture between the summer and autumn wood is in many trees plainly visible, and gives rise to a number of ring-like markings known as **annual rings,** each of which in general represents a year's growth. In forest trees the pith becomes absorbed, and the stem practically consists of older and younger wood and bark. The old or **heart** wood, dark in colour, is really dead, *i.e.*, except as a mechanical support it is of no use to the tree. The younger or sap wood contains the food channels through which the salt solutions pass to the leaves. (See Figs. 38, 39, 40, p. 50.)

The Bark. The bark on a young stem is thin, perforated by minute pores (*stomata*), and contains chlorophyll; hence it is able to absorb and decompose carbon-dioxide. As the tree grows older, a layer of cork forms on the inner surface of the bark, and cutting off food supplies from the outer portion causes this to shrink up and die. The bark then becomes thick and tough, and, as the tree expands, splits from time to time, and gradually acquires the irregular and wrinkled surface characteristic of older trees.

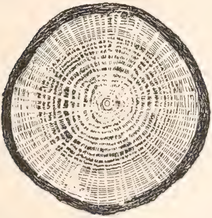

Fig. 38.—Oak-stem cut across to show the annual rings. The new wood (sap-wood) is just below the bark. The rays running from pith to bark form the silver grain.

The bark acts as a waterproof covering confining transpiration to the leaves and green parts, thereby securing the passage of the salt-solutions to these organs, and preventing loss in the food on its passage from the leaves to the growing parts.

UNDERGROUND STEMS.

In the case of many plants the whole of the stem does not rise above the ground, a considerable portion being

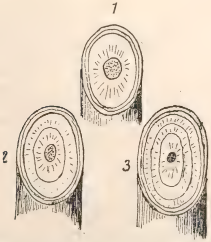

Fig. 39.—One-year old (1), two-year old (2), and three-year old (3) shoots. In No. 3 the inner ring of bark is the new bark, and the third ring of wood, counting from the pith, is the sap-wood (new wood).

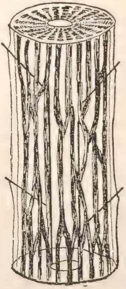

Fig.40.—One-year old stem, showing the pith and the pith-rays (silver grain).

buried in the soil. These underground stems are distinguished from roots *(a)* by their having leaves and buds; *(b)* by the fact of their being continuous with that part of the plant which bears foliage leaves; and *(c)* by their arising in the axils of leaves. The following common types of underground stems or shoots may now be considered: **tubers, bulbs,** and **rhizomes.**

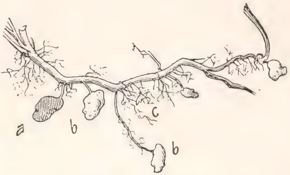

Fig. 41.—(*a*) Old tubers. (*b*) Young tubers. (*c*) Roots.

Tubers. A tuber is an underground shoot consisting of a swollen stem. The Potato-tuber is such a shoot; its eyes are buds occurring in the axils of very small leaves. The tubers, moreover, are continuous with the stem which rises through the soil into the air. If developed above the ground the tubers themselves will bear foliage leaves. The roots of the Potato, for the most part, spring from the lower parts of those portions of the stem which are not swollen.

Bulbs. A bulb is an underground shoot which consists of a short plate-like stem surmounted by thick fleshy leaves. If a Lily bulb be cut down through the centre towards the root, its structure can readily be seen. Notice the buds, recognisable by their enveloping leaves,

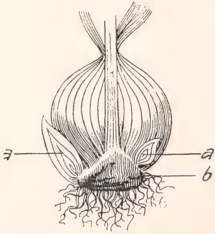

Fig. 42.—Bulb of Lily.
a, Buds; *b*, Plate, the tree stem.

arising in axils of the older overlapping leaves. The roots grow downwards from the base of the stem.

In the Onion the fibrous roots hang downwards from the lower surface of the short plate-like stem. The bulb itself consists of a number of thick white fleshy bases of leaves overlapping each other, and forming the edible part of the plant.

Bulbs usually flower either early or late in the year, at a time not very favourable for the production of food by the leaves. In the case of the Onion a flowering stalk grows up from the centre, blossoms, and produces seed, the food supply for the process being obtained from the swollen bases of the leaves. In the case of the Lily the new leaves work until they have stored up sufficient food for the next season's flower and then die down.

The Rhizome or Root-stock. The Rhizome or root-stock is well seen in many of the grasses, in garden Mint, in the Iris or Flag-lily, and in New Zealand Flax.

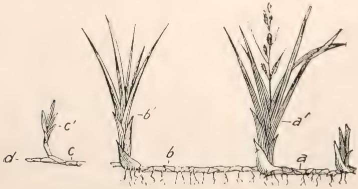

Fig. 43.—Root-stalk of a Perennial Grass.
a a′, first year's growth; *b b′*, second year's growth; *c c′*, third year's growth *d*, terminal underground bud.

In the diagram the underground stem *(a)* gradually bends out of the ground, becomes erect *(á)* and bears flowers. But the base of this erect portion produces a bud which continues to grow under the surface for a short distance, and then in turn bends out of the soil and produces a flower like the first stem. A third stem is formed in a similar manner. In this way plants having root-stocks rapidly extend through the soil, and, when they once take hold of the ground, are very hard to get rid of. They are perennial and live in the soil through the winter though there may be no sign of them at the surface. At every joint these underground stems are able to produce buds, some of which come up through the soil and bear leaves, flowers, and fruit, whilst others produce underground shoots. In this way these structures are able to form a dense interlacing mass of stems beneath the ground. It is very little use to cut them up, for such treatment only serves to establish fresh centres of growth, seeing that every little portion bearing a bud can develop and grow. The only plan is to pull them bodily up, a process requiring much time and labour.

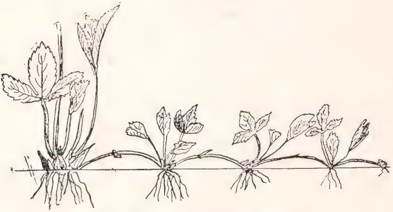

Fig. 44.—Runner of Strawberry Plant.

In the Strawberry the plants produce what are commonly known as runners. A runner develops from a bud which arises in the axil of a leaf, so that it is really a branch. This branch runs along the ground and produces a tuft of leaves, in the axil of one of which a new runner is formed. Below the leaves a number of roots are given off as in most creeping stems. The strawberry differs from some others in that the same branch does not connect the shoots together.

NOTE.—Some of the work outlined in this chapter has already been referred to, and has probably been taken up and mastered by the pupils. As in other cases a summary of the work done in this connection will furnish an excellent introduction to lessons on the stem. In dealing with the thickening of stems, a little judicious questioning will draw out the necessity for the process, the details of which to a large extent will have to be supplied. Pupils can see in good transverse sections the rings of growth, can determine the position of the young wood, and can form a rough estimate of the age of the plant. But the exact positions of the **cambium** and **bast** and the way in which the activity of growth is promoted, cannot at this stage be observed by pupils for themselves. So too for the bark, pupils can be led to understand the conditions which limit its growth and cause it to present the appearance usually seen in the older plants. But to discover all this by observation, if indeed it could be so discovered by the pupils, would mean an immense demand on the time available for the subject.

In dealing with underground stems the tuber should be examined first, the pupils are more familiar with it; besides, the reasons for calling it a stem and not a root are easily and readily grasped by children. Observations might be made on this part of the plant in the Infant Department. Pupils should be required to plant potato "sets" with and without "eyes," and in this way learn that these represent buds. Having once grasped the idea of an *underground stem* as distinct from a root, the other forms recommended will not present much difficulty. A number of other bulbs in addition to those mentioned, should be examined, and if it be thought desirable, *corms* of the Crocus and Gladiolus as well. A good deal of attention should be directed to the form of underground stem known as the rhizome, and its importance as a means of enabling grasses to spread should be made clear. A garden connected with the school would help perhaps more than anything else in enabling pupils to understand the details treated of in this and other chapters.

XIII.—MODES OF CLIMBING.

The stems of many plants are not sufficiently strong to enable them to stand erect, and spread out their leaves to the light and air. These obtain the support they require by leaning against or fixing themselves to other objects. Some of the methods adopted to secure support will be seen by a study of the following:—

Twining Stems. Twining stems are those which find support in twisting round objects that are erect or nearly so. The twining takes place moreover in a definite direction. The Convolvulus, for instance, revolves round the support from right to left, forming a left-handed spiral; whereas both the Hop and the Honeysuckle revolve from left to right, *i.e.*, in a right-handed spiral.

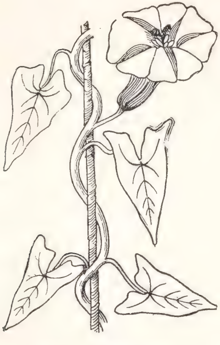

Fig. 45.—Twining stem of Convolvulus.

Root Climbers. The Ivy ascends by means of roots, which it developes on the shaded side, *i.e.*, on the side away from the sun. These roots pour out a sticky fluid which hardens and fixes the plant to the support.

Tendril Climbers. Many plants, *e.g.*, Pea, Vine, Passion-flower, possess peculiar climbing organs named tendrils. On the Pea these occupy relatively the same position as the leaflets further down the leaf-stalk. They are, in fact, modified leaflets. In the Passion-flower, however, the tendrils arise in the axils of the leaves, and hence are modified branches. On reaching a support which, in the case of tendrils, may be horizontal in position, these twine themselves spirally round it and draw up the plant. This spiral arrangement enables the tendril to shorten or lengthen, and to yield to the pressure of wind, etc., when required. In the Virginian Creeper the ends of the tendrils are expanded into discs, which attach the plant to the support by acting as suckers.

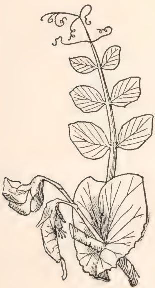

Fig. 46.—Leaf of Pea showing Leaflets converted into Tendrils.

Leaf Climbers. In what is commonly called the garden Nasturtium the leaf-stalks find support for the plant by coiling round slender objects within reach. The same mode of climbing may be observed in the Clematis. In both these cases the stem of the plant itself revolves in order to allow the leaves every opportunity of securing the needed support.

Scramblers. These do not adopt any special method of climbing; they merely lean against and scramble over other plants or objects. In some cases they hold themselves on by means of hooked prickles. In the Bush-lawyer and Blackberry this can be well seen, along the leaf-stalks and mid-ribs, where these plants possess a row of sharp hooks, which enable them to cling with great pertinacity to any object over which they are climbing.

Note.—The work here could be begun in the Infant Department, where pupils could observe some of the methods of climbing, and grasp the idea why it becomes necessary for plants to trust to other objects for support. In St. I and higher classes the treatment of the subject might be extended; pupils could be led to distinguish between the two methods of twining, and in simple cases to determine the organ represented by the tendril. It must not be forgotten, here as elsewhere, that Nature-study is not Botany, and that to enter into considerations involving minute and complicated details and advanced reasoning can result only in failure. Throughout the entire school course it is the simple cases only which should be dealt with.

XIV.—THE FLOWER.

Functions of the Flower. The special duty or function of the flower is to produce seed, and hence to secure the reproduction and multiplication of the plant. Though the structure of the flowers in different groups of plants varies considerably in detail, the same general plan of arrangement will be found in all flowering plants. A pupil will obtain a general idea of the details of flower structure by examining a few typical forms. So soon as the details are mastered, the next step might be to compare and contrast the forms themselves.

The Buttercup. Quite a large number of species of this plant occur in New Zealand, so that during the months they are in flower there will be no difficulty in obtaining suitable specimens.

If we examine the flower, after noting its bright yellow colour, it will be found to consist of (*a*) five green leaves the **sepals,** outside of and surrounding the coloured portion; the whole of these leaves together are known as the **calyx,** and are fastened to the end of the flower-stalk, known as the **receptacle:** (*b*) five yellow **petals** also attached to the receptacle, in such a position as to fill the gaps between the sepals—the whorl of the petals is called the **corolla**, which usually forms the coloured part of the flower: (*c*) a large number of yellow **stamens**, each consisting of a stalk, or **filament**, and a head, or **anther**, and attached to the receptacle—the anther when ripe being full of yellow **pollen** grains: (*d*) a central portion occupied by a number of small green bodies called **carpels**, also attached to the receptacle.

If the flower be cut down the centre, the various parts just described will be clearly seen in position. If now we remove the different parts, we can further examine them in detail. Each petal will be found to be roughly triangular in shape, and to possess at its tapering end a small nectary or honey gland. In the carpel we shall be able to make out a small glistening point, the **stigma**, which is connected with the lower portion, the **ovary**. In the ovary is a little egg-shaped body, the **ovule**. The filament and anther of the stamen and the shape of the receptacle will be seen with much greater clearness in the cut specimen.

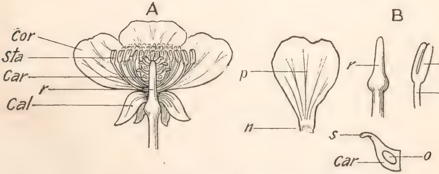

Fig. 47.—*A*, Vertical section of Flowers of Buttercup.
cor, corolla of petals; *cal*, calyx of sepals; *sta*, stamens; *car*, carpels; *r*, receptacle.
B, Flower of Buttercup dissected.
p. petal; *n*, nectary; *r*, receptacle; *a*, anther; *f*, filament or anther-stalk; *car*, carpel; *o*, ovary; *s*, stigma.

The Wall-flower. If the blossom of a Wall-flower be examined in a similar way, the pupil will be able to verify the following description. Four small narrow sepals form the calyx; two of these, standing opposite to each other have honey glands at their bases. Inside the sepals and filling up the gaps between these are four showy petals arranged in the form of a cross, and forming the corolla. The petals are delicately scented and have a soft velvety appearance. Inside the petals and attached to the receptacle are six stamens each, as in the Buttercup, consisting of a filament and an anther lobe. Two of these are shorter than the other four, and are inserted on the receptacle at a lower level than the longer ones. A green nectary is situated at the base of each of the two shorter stamens (the same nectaries as the ones referred to above). In the centre is the **pistil**, a long bottle-shaped body with a slender neck, and a notched and sticky top, the **stigma**. If the pistil be cut through vertically, the lower part, **the ovary**, will be found to be hollow and to contain four rows of **ovules**; these, when the flower ripens, will become the seeds, from which other plants may be grown.

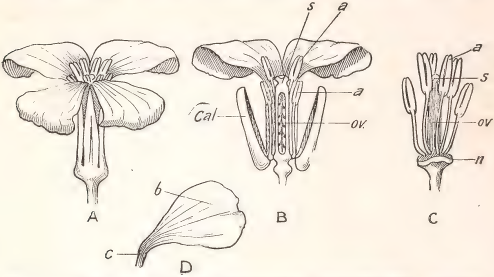

Fig. 48.—*A*, Wall-flower Blossom shewing four Petals arranged in Form of Cross. *B*, Vertical Section of Flower of Wall-flower.
C, Flower of Wall-flower with Sepals and Petals removed.
a, anther; *s*, stigma; *ov*, ovary; *n*, nectary; *cal*, calyx.
D, Petal of Wall-flower.
c, claw; *b*, blade.

We see then that the blossom of a wall-flower consists of a calyx of sepals, a corolla of petals, a whorl of stamens, and a pistil containing ovules.

The Pea Blossom.

Structure of Flower. The Pea blossom is made up of a calyx of five united sepals; a curiously-shaped corolla, consisting of a large upper petal called the **standard**, two side petals known as the **wings**, and two lower petals joined together and forming the **keel**; ten stamens, of which nine have their filaments united to form a tube surrounding the ovary, the tenth being free; and a pistil forming the ovary in which the seeds are ripened.

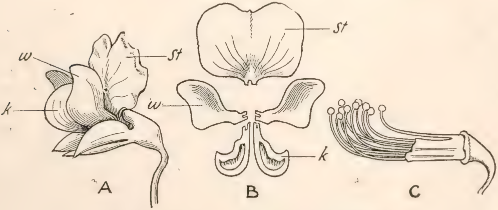

Fig. 49.—*A*, Pea blossom. *B*, Parts of blossom.
st, standard; *w*, wings; *k*, keel.
C, Pea Blossom with Calyx and Corolla removed, shewing the nine united Filaments, the tenth one being free.

The great similarity between the three types of flowers we have examined will gradually become clear. Each possesses a calyx of sepals, a corolla of petals, and a number of stamens with filaments and anther lobes. In the case of the Pea and the Wall-flower, the central portion of each consists of a single pistil containing the ovary. In the Buttercup the carpels which occupy the centre of the flower correspond to the pistils of the other forms. An examination of a number of other flowers will make this similarity of structure still more clear.

NOTE.—A study of the flower in detail might with advantage be left until pupils reach St. III. For a lower standard the detailed observation demanded would prove extremely tedious, and the terminology, which must be learnt, in all probability would either be imperfectly known or cause a dislike for the whole subject; besides there is plenty of other material for the lower classes to work on.

Pupils should examine a number of flowers of the same type and gradually become familiar with the terminology employed. If, for instance, the Buttercup be first dealt with, flowers of several species of this genus should be examined (there are quite a large number of these available) as well as those of other related plants, *e.g.*, any common variety of Single Anemone, the Columbine, Larkspur, etc. An investigation of the flower of the garden Pea could be followed by an examination of those of the Bean, Furze, Wistaria, Dolicus, Yellow Kowhai Clianthus, and other allied forms. Here again we must be careful not to allow the instruction to merge into a training in botany.

A good plan, where it is possible, *i.e.*, where the structure is simple, is to require pupils to remove the various parts from the flower, to place them carefully on their slates, and to draw and name them. When the classes are not too large, the pupils might be required to mount dried specimens on paper. These mounts should show (*a*) the entire flower; (*b*) the parts of the flower in detail.

XV.—FERTILISATION AND POLLINATION.

Fertilisation. In order that an ovule may become a seed, its contents must come into contact with the pollen from the anther lobes. The fusion of the contents of a pollen grain with the ovule is called fertilisation. When the pollen grains fall on the stigma of a flower, the sticky fluid with which the stigma is coated serves not only to secure the pollen, but stimulates the grains to growth. Each grain sends out a pollen tube; these grow down the pistil and reach the ovary. Here each one finds its way to an ovule, and enters the ovule through a small opening (the **micropyle**). The living matter of the pollen tube then fuses with that of the ovule and fertilisation is secured.

Pollination. The transference of the pollen from the anthers to the stigma is known as pollination. The simplest form of pollination is when the pollen is transfered from the anther to the stigma of the same flower. This is known as **self-pollination,** and such a flower is said to be self-pollinated. When, on the other hand, the pollen from one plant finds its way to the stigma of a flower growing on another plant of the same kind, it is said to be **cross-pollinated.**

It has been proved that cross-pollination results in producing a larger yield of seed, and moreover, seed which grows into larger and healthier plants. Hence it is highly desirable that cross-pollination should take place, and various arrangements exist in flowers for bringing this about. A detailed account of these arrangements would be beyond the scope of this work. The following, however, may be mentioned. Sometimes the stamens and pistil do not occur on the same plant—well seen in the staminate and pistillate flowers of the Clematis and Bush-lawyer, which grow on separate plants. Then again, cross-pollination is brought about in the case of many plants having both staminate and pistillate flowers on the same individual—by the agency of insects attracted by the brightly coloured blossoms, by the perfume, or by the sweet nectar possessed by many plants; bees and other insects fly from flower to flower and in doing so carry the pollen from one plant to another. If a bee be watched visiting the blossoms of a Pea-plant the whole process can be observed; the insect alights on the "wings" of the flower and its weight lowers these and pulls down the "keel." The result of this is that some of the pollen is brushed off the anthers and scattered on the bee. The pollen sticks to the bee's body and some of it is certain to be carried to the stigma of the next flower the bee visits. The shape of the corolla is in this case specially adapted to cross-pollination by insects—for the nectar or honey gland is so placed that in order to reach it the insect must liberate and carry off some of the pollen. Quite a number of other flowers have special contrivances for securing cross-pollination by insects—such flowers in nearly all cases are bright-coloured or scented, possess nectaries for the sake of whose sweet juice the insects visit them, and their stigmas are usually small. Cross-pollination may also be brought about by the agency of wind. The anthers contain an immense number of pollen grains, and these, on being liberated, are scattered by the wind in all directions and often carried to considerable distances before finding a resting place on the stigmas of suitable flowers. The grasses, for instance, are pollinated in this way. If an ear of Wheat be examined when green, it will be found to consist of several rows of small flowers arranged upon a central stalk. A number of little yellow bodies will be seen hanging out of each ear—these are the stamens. The anthers are attached to long filaments and hang freely out of the flowers, so that the pollen on being liberated may be

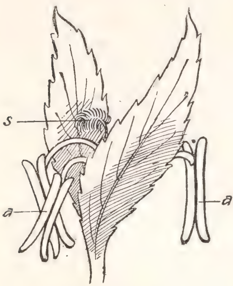

Fig. 50.—Wheat Flower.
s, stigma; *a*, anther.

readily carried away by the wind. The stigma, moreover, is feathery, exposing a large surface to catch the flying pollen grains. The following characteristics will be noted in wind-pollinated flowers. They are *small*, *unscented*, and *not brightly coloured.* They have *no nectaries;* their anthers are attached to *long* filaments and hang freely out of the flower; their stigmas are *relatively large*, and the flowers usually produce a *large* amount of pollen.

NOTE.—If it be considered desirable, this phase of the subject may be entirely omitted—though it seems a pity that a matter of such importance should be left out altogether in a scheme of Nature-study.

When taken up, it should, if possible, be dealt with out of doors, where it can be invested with very considerable interest and made the medium for much thoughtful observation. If time cannot be found for field work, the lessons must be fully illustrated by specimens and drawings.

A good deal of information will have to be supplied—pupils for instance cannot observe for themselves the process of fertilisation. It is not necessary however, that anything beyond a general outline of the process be attempted, just sufficient to enable pupils to understand its object and how it is secured.

Lessons on fertilisation and pollination can be intelligible only after the structure of the flower has been mastered; the work suggested in this chapter should not be taken up until towards the end of the course.

XVI.—THE FRUIT.

That part of a single flower which remains after fertilisation until the seeds are ripe is called a fruit.

So soon as the process of fertilisation takes place, the ovules, we have seen, gradually change into seeds. The consequences of fertilisation, however, are not confined to the ovules. The other parts of the flower—stamens, corolla, and calyx, having finished their work, as a rule, wither and fall off. One part of the flower the ovary (or ovaries) always remains to furnish a protective covering for the ripening seeds. The receptacle and the calyx may also persist—but the stamens and corolla almost always wither and drop, and hence take no part in the formation of the fruit.

We may for our purpose divide "fruit" into (1) Simple fruits or those produced by a single ovary, consisting of one or more carpels or chambers; (2) Compound fruits, made up of a number of simple fruits.

SIMPLE FRUITS (DRY).

The Pea. The fruit of the Pea consists of a pod; which is the enlarged ovary composed of one carpel. The pod readily splits into two portions, the junction between the two halves being well marked. The seeds, which are soft and succulent when young, are attached by short stalks to the inner and front surface of the pod, along the line junction. When ripe, the seeds are hard and dry, and the pod splits along both back and front margins in order to liberate the ripened seeds. Such a fruit is called a *legume*—other examples will be found in the broad bean, French Bean, Clover, etc., etc.

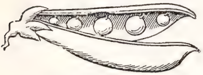
Fig. 51.—Fruit of Pea.

The Wallflower. The pistil is the only portion of the flower which remains after fertilisation. As the seed ripens, the ovary, which consists of two carpels, increases greatly in size. At last the wall of the ovary splits in such a way as to

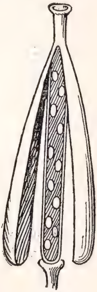
Fig. 52.—Siliqua of Wallflower.

form two flaps. These beginning at the bottom gradually become free, and expose a central plate, on either side of which the seeds are arranged.

A fruit of this kind is called a *siliqua ;* further examples will be found in the Single-Stock, Cabbage, Turnip, and other well-known plants.

The Poppy. The fruit of the poppy consists of a swollen pistil which forms the globular capsule known as the poppy head. The top of the fruit (the head) is the stigma which has remained. If this be removed, the seed will be seen arranged along the walls of a number of separate chambers ; just below the head is a row of small openings running completely round the fruit. As this hangs inverted on the end of the flower-stalk, it is shaken about by the wind and the seeds fall out through the openings. A fruit of this kind is called a *capsule.* Other examples of capsules will be found in the Iris, the Fox-glove and the Violet.

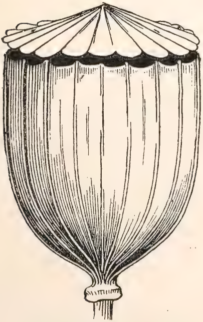

Fig. 53.—Capsule of Poppy.

It will be noticed that the simple fruits just described, viz., the legume, the siliqua, and the capsule, are dry fruits.

The Hazel Nut. The fruit of the Hazel tree is dry and woody and does not open of its own accord—such a fruit is called a nut. The shell of the nut consists of three layers and contains a single seed—commonly called a kernel. Compare with the fruit of the Rimu, which is also a nut.

The Acorn Nut. The fruit of the Oak tree is called an acorn. Its lower part is inclosed in a cup. If the shell be removed, the nut will be found to contain a single seed only, which consists of two large fleshy cotyledons.

SIMPLE FRUITS (FLESHY).

The Apple. The fruit of the Apple is simple, for it is the product of a single ovary; it is also fleshy and of varying shape. Its skin is smooth and tough, and varies in colour with the season of the year and the kind of apple. A tough stalk made of woody fibres supports the fruit which shows a deep depression where the stalk is attached, and a shallower one on the opposite surface, both being circular in shape. Projecting from the bottom of the upper and smaller depression is a tuft of small withered leaves—these are really the remains of the sepals which originally enclosed the flower. Inside the skin is the fleshy pulp, and in the centre of the fruit is the compartment which contains the seeds. It is five chambered, surrounded by a tough skin, and with the enclosed seeds is known as the **core.** The five chambers of the core represent the carpels of the pistil.

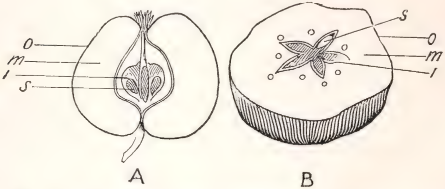

Fig. 54.—Fruit of Apple. A, Section through Apple from stalk to crown. B, Cross section.
o, outer layer of covering; m, middle layer; i, inner layer; s, seed.

The fleshy part of the Apple is the swollen receptacle in which the five carpels of the pistil are buried. As the seeds ripen, the receptacle increases in size, becomes sweet and fleshy, and finally composes the greater part of the fruit. The seeds (pips) are pear-shaped; each is covered by a dark brown shiny skin and contains the embryo.

It will be seen that the apple is an example of a fruit formed largely by the receptacle. The Pear is another example. The fruit of these trees is known as a *pome.*

The Plum. The fruit of the Plum, like that of the hazel-nut, consists of a seed enclosed in a covering. The covering comprises an outer skin, a hard horny layer known as the stone, and lying between these a sweet juicy mass, the flesh of the fruit. The three parts of the covering in this case correspond to the three layers composing the shell of the Hazel-nut. A fruit of this kind is called a *drupe.* The Cherry, Apricot, Peach, Karamu (*coprosmas*), Totara, Kaikatea, Matai and Miro are other well-known examples.

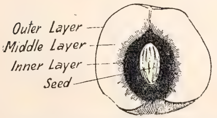

Fig. 55.—Peach drupe cut through, shewing stone.

The Gooseberry. In this case the seeds are imbedded in a soft sweet juicy pulp, the covering, which is hard in the Hazel-nut and Acorn, being modified to form the thin outer skin and the soft pulp within. Such a fruit is called a *berry.* Other plants whose fruit are berries are the Fuchsia, Potato, Poro-poro (*solanum aviculare*), and Cabbage tree (*Cordylene australis*).

Compound Fruits.

The Fruit of the Rose. In the Wild Rose or Sweet Briar the fruits are called "hips." They are oval in shape, with a flat circular rim above, which is marked with five scars. These show the former position of the sepals. Sometimes the sepals themselves remain. In the centre of the rim is a depression filled by a number of hairs, which, when the fruit is opened, are seen to be the styles of the carpels. The carpels themselves are covered with fine soft hairs, and are closely packed round the sides and on the bottom of the cavity ; each hairy carpel contains a seed enclosed in a hard and tough covering. If the "hip" be compared with the flower of the rose, it will be seen that the oval body containing the carpels is the developed and swollen receptacle.

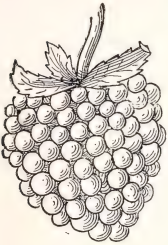

Fig. 56.—Fruit of Blackberry.

The Strawberry. The fruit of this plant consists of a swollen and juicy receptacle, which has grown up on the inside of the carpels. These are dotted over the fleshy surface of the receptacle, and each contains a seed.

The Blackberry. The fruit of the Blackberry and Raspberry consists of a number of drupes (*i.e.*, fruits like those of the plum or cherry) arranged round a central axis, the receptacle. In this case the calyx has persisted, and may be seen at the base of the fruit.

NOTE.—On this part of the subject a beginning might be made early in the course—such fruits as the apple and peach make splendid subjects for observation and language lessons in the lower classes. The distinction between seeds and fruits and the more systematic investigation of the latter, if undertaken at all, should be reserved for the upper standards. Here, again, much will depend on the conditions and surroundings of the school, and on the teacher. A good deal of the work is best undertaken in the field ; but all of it is capable of demonstration indoors. Much of it, however, will fail as a medium of education if not directed by a teacher possessing both knowledge and skill, hence the amount to be attempted will depend largely, if not entirely, on the knowledge equipment and tastes of the teacher—in short, this particular part of the course should cease where dogmatic teaching begins.

XVII.—THE DISPERSAL OF SEEDS.

Plants, unlike animals, are unable to move about ; hence a flowering plant is to all intents and purposes confined to the spot on which it grows. Its seeds, if not dispersed, would fall to the ground close by the parent plant, whose shade and presence would greatly interfere with vigorous growth. Besides, the soil in the immediate neighbourhood of the parent plant might be unsuitable, to say nothing of the interference with the proper development of the seedlings in consequence of overcrowding. For these and other reasons it is necessary that seeds, so soon as they are ripe, be scattered as widely as possible.. Hence many plants have special arrangements by means of which their seeds are conveyed to places suitable for germination.

Dispersal by the Wind.—To secure dispersal by the wind many seeds are provided with outgrowths of various kinds which, by offering a larger surface to the wind, without appreciably adding to their weight, cause them to be carried along frequently for a considerable distance before falling to the ground. The seed of the Hakea and Sycamore is furnished with wings, that of the Thistle and Dandelion with a tuft of radiating hairs; whilst the seed of the Clematis has a long feathery style. It may be mentioned that seeds furnished with wings are invariably found on trees which grow to some height. The utility of this arrangement is not difficult to understand. If the winged seeds were borne by low growing plants, they would fall to the ground long before the wind could carry them any distance.

There are other seeds which the wind helps to scatter and which are without appendages of any kind. The seeds of the Poppy, Violet, and Pansy, are shaken out through little openings in the capsule, whilst those of the wall-flower fall off from the central plate as the siliqua opens; these plants, in fact, sow their own seeds.

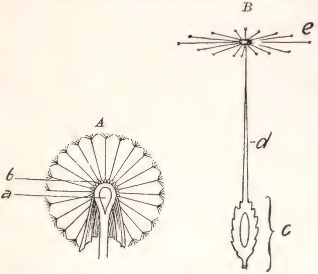

Fig. 57.—*A*, Section through head of dandelion. *a*, receptacle; *b*, seed.

B, Section through single seed. *c*, seed; *d*, elongated calyx tube; *e*, tuft of hairs.

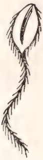

Fig. 58.—Seed of Clematis, showing feathery plume.

Dispersal by Clinging to Animals. Many seeds and fruits possess hooks, or rough or sticky surfaces, which enable them to cling to animals as these brush past them. In the Piri-Piri, usually called “ Bid-a-bid,” the ovary is covered with hooked spines—the whole forming the burr by which the seed is distributed.

Dispersal by Birds. Seeds that are dispersed by the wind or by clinging to animals are usually dry, whilst those that are dispersed by being carried inside animals possess brightly-coloured fleshy coverings, which attract animals both by their appearance and taste. When the fruit is eaten, the seed being protected by a hard indigestible stone or covering passes through the body of the animal uninjured.

Many birds, for instance, are extremely fond of Blackberries, and carry the seeds in all directions. This is one of the chief reasons why it is so difficult to get rid of this troublesome plant, which has long since found a place amongst the "noxious weeds." The fruit, instead of being devoured where it grows, is frequently carried to some quiet spot, to be eaten at leisure, or, whilst being carried away, often escapes from the beak of the bird and drops to the ground. In the same way the so-called berries of the Puriri tree are scattered over wide areas by the wood-pigeon. Many other kinds of fruit and seeds will suggest themselves in illustration of this mode of dispersal. It will be noticed, moreover, that most of the fruits or seeds dispersed in this way are red in colour—this being the colour which appears most conspicuous amongst the green foliage.

NOTE.—The dispersal of seeds may be begun in the Infant Classes, and referred to from time to time during the course. The details of dispersal, however, can hardly be discussed with much fullness until pupils possess some knowledge of the flower.

The spread of noxious weeds is already causing grave apprehension in many of our country districts. It is important, therefore, that these lessons be dealt with in such a way as to direct special attention, not only to methods of dispersal—but also to the need for checking the spread of harmful plants. A knowledge of the former will be of great assistance in accomplishing the latter.

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XVIII.—GRASSES.

General Character of Grasses.—The wild and cultivated grasses are generally slender leafy herbs, seldom more than two or three feet in height, with hollow jointed stems, and narrow, flat or rolled, and often strap-like leaves. The grasses cultivated for their grains and known as **cereals,** are taller and stouter, *e.g.*, Oats, Wheat, Maize. In our warmer districts Maize and Bamboos grow freely. These are among the tallest and stoutest grasses found in any part of the world. The flowers of grasses are very simple and in many ways unlike those of any other family of plants.

A TUFT OF COCKSFOOT GRASS.

Cocksfoot Grass (*Dactylis glomerata*) is very common in pastures and by waysides, and also in gardens and orchards, for it thrives in shady situations better than most other grasses. For this reason it is known as "Orchard grass" in the United States of America. Loosen and pull up a small tuft and shake off or wash away the soil. Notice the rather stout branches creeping and rooting where they rest on the ground. The branches are short and spring from the bases of the lowermost leaves

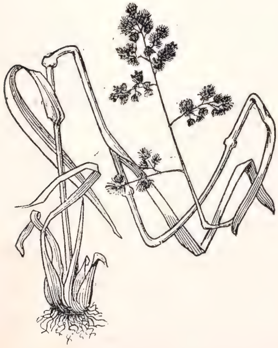

Fig. 59.—Tuft of Cocksfoot, showing inflorescence.

of older stems or branches. Branches of this kind are known as **stolons.** Observe the many thread-like or fibrous roots springing from the lower part of the stem and from the under surface of the stolons. The roots are long and pass deep down into the soil, so that Cocksfoot resists dry weather well. Note the numerous basal or **radical** leaves, forming small tufts at the bases of the stems and of the still barren side shoots. Notice that the roots do not come from a main tap root, but grow in smaller bunches from the bases of the leafy stems and branches. The roots grow in this way in most plants that have a single seed-leaf (Monocotyledons). In the warmer season flowering stems or **culms,** as they are called, grow up from the better grown branches. Find a "culm" and note that it is long, slender, jointed, and clothed with leaves almost to the top. When full-grown, each "culm" ends in a branched cluster of flower-bearing organs. Note that each leaf on the culm springs from a joint or **node.** The part between two successive nodes is called an **internode.** Note the number of joints and internodes on the culm; cut down along part of the culm and notice that it is hollow throughout the internodes and solid at the joints or nodes. Notice that the joints are sometimes thicker at one side than at the other. The use of the solid joints is to keep the culm erect, and they do this by growing thicker at the side that is turned more towards the ground.

Remove a leaf from the lower part of the culm. Note its bluish-green colour and that it springs from a joint. Cut down through a joint and notice that the firm projecting ring is formed by a swelling of the lower part of the leaf. Note now the two chief parts of the leaf—the basal part, or **sheath,** wrapped round the culm, and split on one side along its whole length; and the **blade,** long, folded, and standing off at an angle from the culm. Note the parallel veins of the leaf (a character common to most Monocotyledons) and the well-marked mid-rib; also that the leaves are broad, thick, and juicy. Look carefully at the spot where the sheath and the blade meet, and note the thin scale-like outgrowth named the **ligule.** A ligule is very generally present in the leaves of grasses, and it always has the same form in each distinct kind or species. Its form should always be carefully noted, as grasses that are very much alike when out of flower can often be clearly distinguished by the ligule. Sometimes the ligule is wanting or absent, and sometimes, as in the native species of *Danthonia,* it has the form of an incomplete ring of hairs. Note how the leaves are arranged on the culm; a leaf on one side is followed by a younger leaf on the opposite side. The leaves are said to be **alternate** on the stem. Pull the top of a green culm out of the leaf sheath. Notice its pale colour and that it is juicy and fragile. The sheath protects and supports the tender lower part of the internode—the part where growth in length is going on. Chew the lower end of the internode pulled out of its sheath and note its sweet taste. It contains a little sugar. Some grasses, such as the Sugar-cane and Black Millet (*Sorghum*) contain a great deal of sugar.

Find a full-grown culm with the flower-bearing branches at the top. Note that the flowers grow in very small flattened clusters called **spikelets.** The spikelets are crowded together into thick oval masses and are all turned to one side. Each spikelet contains three flowers (sometimes more, sometimes fewer). The parts of a spikelet can be better seen in the Oat or in Wheat. Note here the two chaffy scales or **glumes** placed outside the flowers and protecting them, and later on protecting the "seed" also These glumes are called "empty glumes."

Find a culm with the flowers open. Note that they are small and inconspicuous, though their dangling violet-tinted anthers lend them some beauty. At the base of the stamens look for the ovary with its two feathery stigmas. For seeing these a common pocket magnifying glass will be helpful, and with its aid you will probably be able to make out the pollen grains on the anthers of the stamens. In most grasses the anthers hang out in the way observed here. They thus allow the pollen to be easily wafted from plant to plant by the wind. The stigmas are branched and feathery in order the more easily to catch the pollen grains that are blown about by the wind. Nearly all grasses are fertilised by the wind, and this often brings about **cross-fertilisation**, the pollen from one plant fertilising the ovary of another one. Sometimes the pollen is ripe and scattered abroad before the ovary of the same flower is full-grown. This makes cross-fertilisation more certain. The "seed" formed after cross-fertilisation produces more healthy and vigorous plants than when the flowers are self-fertilised. Rub in your palms some spikelets well past flower and examine the minute seeds. Note that each "seed" consists of a thin scaly husk (the flowering glume and palea) and the grain or fruit held more or less loosely within them. These parts can be much more easily seen in Wheat or Oats, and some ripe heads of these grasses should be ready for showing the **husk** and **fruit**. The grain of a grass is a true "fruit" for it consists of the full-grown or ripened ovary, which then contains a single seed filling the whole of its cavity. What is commonly called the "seed" of

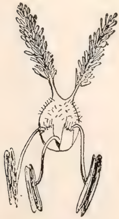

Fig. 60.—Flower of wheat with scales removed, showing loose anthers and feathery pistil.

a grass really contains the true fruit together with the husk (the flowering glume and palea). A grass "seed" is therefore improperly named, and is in no way comparable with true seeds such as those of the Pea, the Violet, the Wall-flower, &c.

Spikelets and Inflorescences. Examine either Red Top (Bent grass—*Agrostis vulgaris*) or Fiorin Grass, when in flower. Note the small spikelets, and that each has but a single flower (one-flowered spikelet). Notice the branching at the top of the culm; several whorls of delicate branches come off from the main axis of the culm, and they may branch again and even again. Each ultimate branch bears a small spikelet, and all the spikelets are stalked. Note the ligule.

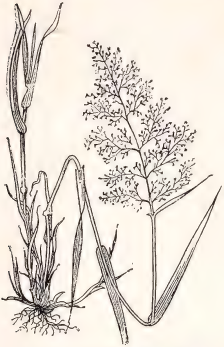
Fig. 61.—Fiorin grass; panicle inflorescence.

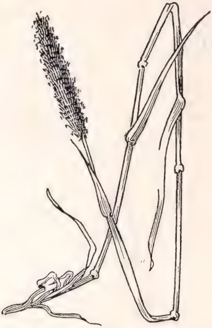
Fig. 62.—Meadow Foxtail.

The arrangement of flowers or of spikelets on a flowering axis or on its branches is called an **inflorescence.** In Red Top the branched inflorescence is named a **panicle.** A great many grasses have an inflorescence of this type. Compare the inflorescence in the Oat, Smooth Meadow Grass (*Poa pratensis*) and Yorkshire Fog. In each it is a **panicle.**

Examine a spikelet of Sweet Vernal Grass (or of Timothy Grass or of Meadow Foxtail). Note that the spikelet is **one-flowered.** Bend the flower-head to one side and note the short branches supporting the spikelets. These branches are very short so that the inflorescence is very compact **(a spike-like panicle).** Note the number of stamens in Sweet Vernal Grass. Examine a tuft of Yorkshire Fog, when in flower. Notice the soft velvet-like hairy-covering of its leaves. This makes them difficult to wet, and for this reason, and because they have a bitter flavour, the grass is distasteful to stock. What kind of inflorescence has this grass? Note that the spikelets are two-flowered, and that there is a short awn or bristle on the back of the "flowering glume"—the larger and stiffer glume facing the flower. Examine the ligule: it is short and oblong.

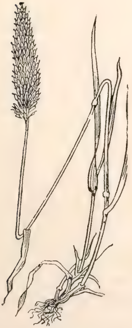

Fig. 63.—Sweet Vernal Grass.

Examine a head of Oats. Note the spreading open panicle and the drooping spikelets. As these are large, their chief parts can be easily made out. Notice the two long outer glumes (chaffy when ripe); and within them the stiffer convex "flowering glume" facing the shorter more delicate two-nerved "palea." Between the "flowering glume" and the "palea" lies the flower. It has no calyx or corolla, but has three stamens and an ovary or pistil, with two feathery stigmas. On the back of the flowering glume notice the prominent awn. Awns are found on the flowering glumes of many grasses, and sometimes on the empty glumes also. They are often rough or bent, and serve to catch in the hair or feathers of animals. They thus help to spread the seeds about. In some grasses the awns by twisting and untwisting, according as the air is dry or moist, help to bury the seeds in the soil. Count the number of flowers in each spikelet. One of the flowers is often imperfect. Note that the grain or fruit is easily separated from the husk. This is still easier when the "seeds" have been well dried in a kiln.

Examine a piece of one of the native *Danthonias* when in flower. Note the kind of inflorescence, the number of flowers in each spikelet, and the peculiar ligule. Rub some flowers out of a ripe spikelet. Notice the large tufts of hairs on the flowering glume, also the awns that are often twisted at the base in corkscrew fashion. These tufts of hairs cause the "seeds" to be carried about by the wind. This is why this grass grows up so readily on waste land. In Briza (Quaking grass) the whole spikelet is light and inflated. When ripe it falls off and is blown about. This pretty but useless grass has thus been spread all over our waste land.

Examine a small tuft of Rye-grass. Note that the leaves and culms are glabrous (quite free from hairs). Look carefully at the inflorescence: the spikelets are alternate and without stalks on the axis of the culm. This type of inflorescence is called a **spike.** Note that each spikelet has only a single empty glume. The flattened axis sufficiently protects the inner face of the spikelet. The spikelets are three- to many-flowered. Note the prominent midrib and the well-marked folding of the lower part of the blade. The leaf-sheaths, too, are flattened, and are thus less readily injured by the trampling of cattle. They are reddish towards the base. Compare with this the inflorescence of Wheat (a compound spike), Barley, and the native Blue Oat Grass (*Agropyrum scabrum*).

From our examination of the grasses we have studied, we learn that grasses have two types of inflorescence, the **panicle** and the **spike**, and that the number of flowers in each spikelet, may be one, two, or more. In grasses with one or two flowered spikelets the number of flowers is generally constant. Where the number of flowers is greater, it is more or less variable.

A Typical Sward or Creeping Grass. Dig up a small patch of Smooth Meadow Grass (Kentucky Blue Grass, *Poa pratensis*), and shake off the soil. Observe the slender widely creeping rootstock, producing few or several flowering stems and numerous underground stolons. At a short distance from the parent plant the stolon forms new roots on the under side and sends up a tuft of leaves on the upper. Next season these barren tufts will produce one or more flowering stems, and give off a fresh crop of stolons, which will form new rooting and leafy tufts as before. In this way every bit of unoccupied ground near the plant is overspread and a close sward of grass is formed. This grass is thus a vigorous and aggressive perennial, being able to spread rapidly when closely cropped and even when entirely

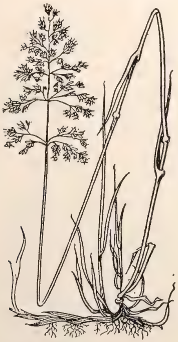

Fig. 64.—Smooth-stalked Meadow Grass.

prevented from flowering and fruiting. Examine a culm of this grass; note the leaf folded in the bud (compare Cocksfoot in this respect), the prominent obliquely truncate ligule, the paniculate inflorescence, the three- or four-flowered spikelets, and the webbing of tangled hairs at the back of each flowering glume. The glumes are without awns. *Poa pratensis* is an early grass. It is a very permanent grass in pastures, and very undesirable in fields that are ploughed for cropping every few years. Every joint of the stolons is able to grow, so that the plant is exceedingly difficult to get rid of under cultivation. It is often called "couch grass;" but this name should not be used, as the true "couch grass" of Great Britain is a kind of *Agropyrum* with the inflorescence a **spike,** and is much more like a rye grass than like a *Poa*.

Maize or Indian Corn. Maize is a native of South America and was cultivated by the American Indians long before the New World was discovered. It is the tallest and stoutest of the cultivated **cereals.**

Observe its large long shining succulent leaves and its numerous nodes. Cut down the stem and note that it is hollow like ordinary grasses. When in flower make out the remarkable double inflorescence—the female and the male. The female inflorescence is produced in the angles or **axils** of the middle leaves of the stem; the male inflorescence is produced at its top. Note the thin leafy overlapping bracts that enclose and protect the female inflorescence. This consists of a club-shaped body called the "cob," apparently formed of a number of spikes that have grown together. No other grass has an inflorescence like it. Each cob bears many rows of female flowers (pistils or ovaries). Note the long thread-like styles projecting from the top of the enclosing bracts and springing from the ovaries of the cob. The styles are all papillose (covered with minute knobs) that they may catch the pollen the better. The male inflorescence is a terminal panicle with the spikelets sessile (without stalks) and in pairs. The pollen shed from the ripe anthers is blown about and thus reaches the styles. Cross fertilisation must occur very frequently. Examine a plant when the "cobs" are ripe and note how they are covered and protected by the husk—the tuft of dry withered tough bracts. Owing to this and the hard polished surface of the grains, the ripe cobs and grains take no harm from bad weather, and may be safely left on the plants for many weeks after the crop is ripe. This makes the harvesting of Maize an easy affair. Examine a ripe "cob." Note the numerous rows of "grains" reaching along the whole length of the core. Young Maize plants are often set out by hand, after they have well started growth. This is because the plants grow very large and need to be kept a good space apart from each other. It also allows of their being kept in rows, an arrangement that makes weeding and hoeing easier. The dried leaves are sometimes used as fodder.

Annual and Perennial Grasses. Some grasses ripen seed every year and then die. These are called **annual grasses.** All the cereals belong to this class; so do the common wayside meadow grass (*Poa annua*), Quaking Grass (Briza) and several weedy Fescues and **Brome Grasses.** Annual grasses are often very troublesome weeds, as they produce abundant "seed" that germinates quickly and certainly. *Poa annua* is one of the worst weeds of the garden.

Grasses that grow for more than two years are called **Perennial grasses.** Each year they produce, besides flowering stems, a number of leafy barren stems that will form flowering stems later on. Perennial grasses are tufted or spreading according to the nature of their branches or stolons. All the valuable pasture grasses belong to this division—*e.g.*, Rye-grass, the useful Meadow Grasses, Cocksfoot, Timothy, Meadow Fox-Tail, Red Top, &c.

Uses of Grasses. No other family of plants is more useful than the grasses, or will grow in a greater variety of situation. Their foliage forms the chief food of our domesticated animals (cattle, horses, sheep, goats), and they are extensively cultivated for fodder (hay). The **cereals** (Wheat, Oats, Barley, Rye, Rice, Millet, Maize) are all cultivated for their grains, which form the staff of life in all civilised countries. The grains of Oats, Maize, and Wheat are also largely used for feeding horses, pigs, and poultry. In tropical countries vast quantities of sugar are prepared from the sap of the thick succulent stems of the Sugar Cane. Paper-pulp is also prepared from the leaves of many grasses. Beer and whisky are made from malted Barley. Starch is prepared from the grains of several cereals. In tropical countries Bamboos serve a bewildering variety of uses.

Many grasses are highly ornamental and are grown in gardens for their beauty. Among these are Bamboos, the Danubian Reed (*Arundo donax*), Pampas Grass, the native Toi Toi (*Arundo conspicua*), &c.

Tillering of Wheat and Oats. In a Wheat or Oat field you may notice a number of flowering stems growing up from a single plant. This is because the plant has produced a number of stout stolons (side branches) each of which produces a flowering stem. Rolling the fields while the plants are still young, helps to make them "tiller" or send out a number of side shoots. For the same purpose calves and sheep are put into the fields to eat back the main shoots. Anything that checks the growth of the first or main shoot tends to make it "tiller." It is because of this habit that Oats and Wheat yield such heavy crops in spite of the inroads of birds and the rotting of numbers of the "seeds."

Distinguishing Grasses. When in flower grasses can usually be readily distinguished by the character of their inflorescence, their spikelets, and their flowers. Dried specimens should always be in flower or in fruit, and it is best to have both.

When not in flower, they are much more difficult to distinguish; but careful attention to the hue, the form, the clothing, and texture of the leaves; to the form of the ligule, and its presence or absence; and to the habit of growth—will enable any careful observer to tell all the most common and important grasses with certainty.

NOTE.—This part of the subject should be deferred until pupils reach the higher standards; for only the most elementary examination of grasses will be within the grasp of the younger children.

It is needless to say that with a little trouble grasses can always be obtained for investigation. They may be examined either in the schoolroom or in the field—in neither case should there be much difficulty in procuring plenty of specimens to pass round the class.

In order to study grasses to any purpose, it is necessary to collect, press, and dry small tufts of the plants when in flower or in early seed. Work of this kind might be undertaken by the older pupils, who during its progress would not only learn much of the habits and general characteristics of grasses, but would learn to recognise many of the commoner forms.

To prepare specimens, small tufts are laid out in a natural way on sheets of dry paper—newspaper does well enough—these are called *specimen sheets.* Above each specimen sheet some empty sheets are placed, and on the top of these another specimen sheet, then some more empty sheets and so on. When the pile is complete the whole is pressed between flat pieces of board weighted above by two or three bricks or other heavy objects. The pressure keeps the plants from shrivelling and shrinking. The pile should be placed in a dry place where the sun and wind can get at it well. In general the empty sheets should be changed for dry ones two or three times, and the whole should be kept under pressure until the plants are dry and stiff. A number of detached flowering heads should be dried with each tuft, that there may be plenty of material for studying the spikelets and flowers.

In most localities specimens of the following grasses can be readily collected and dried—Red Top or the allied Fiorin Grass, Perennial Rye-grass ; Sweet Vernal Grass, Yorksire Fog, Cocksfoot, Smooth Meadow-grass, the Oat, and Wheat.

In drying ordinary flowering plants the paper must be changed more frequently—indeed once or twice daily for several days.

XIX.—PHORMIUM OR NEW ZEALAND FLAX.

Phormium or native flax belongs to the great family of Lilies, and is found in abundance in both Islands. It grows best in moist situations, reaching its greatest size in the rich alluvial soil along the banks of rivers, where the roots are abundantly supplied by water that never stagnates about them.

Notice that the leaves do not grow singly, but spring from the underground stem in the shape of a **fan**, which sometimes consists of a dozen or more leaves. Each fan produces from five to six leaves every season.

The Stem. Dig up a portion of a flax clump, and notice the thick underground creeping stem (*rhizome*) with its numerous fibrous roots. Compare with the stem of the Iris or Flag-lily. Notice the buds every here and there on this underground stem. From these new fans are developed which gradually acquire their own roots, and finally become independent plants, clustering together and forming the familiar " flax bush." In the course of a few years a seedling plant will in this way grow into a large clump.

The Fan. Examine a leaf growing from the stem. Ascertain that it consists of a long sword-like blade, ending above in a point—though the upper part of the blade is almost always split for some distance from the apex—and below in a thickened butt, formed by the two halves of the leaf on either side of the mid-rib being fused together. Notice that the partial fusion of these further up the leaf forms a sheath on one side and a keel more or less deep on the other. Notice the leaf arrangement forming the fans. The keels all point outwards and the sheath of each leaf for some distance from the underground stem encloses the keel of a neighbouring one, the central leaf being wrapped on either side by a sheath.

Observe the sticky fluid which oozes out of the thickened end of the leaf. The dressing of the leaves is greatly interfered with by the presence of this gum.

When it has grown for several years, each fan sends up a long flower-stalk or **scape**, called by the Maoris a Korari, after which it produces no more leaves but dies the following year.

The Flower. Examine one of these flower-stalks. Ascertain by cutting it that it is not hollow, but consists of bundles of coarse fibres closely packed together. Notice the sheathing **bracts** which occur at intervals throughout its entire length. Observe that each bract at its base completely envelopes the stalk, and grows towards the side of the stalk opposite to that towards which the next higher or next lower bract points. Notice that the intervals between the sheathing bracts diminish in length towards the top of the flower-stalk, where they become crowded together. Notice further that about half way up the stalk each bract encloses a small, stout, lateral branch bearing flowers. The bracts, which are at first green, gradually become dark brown in colour, and wither away.

Examine one of these branches, and observe that the flowers are borne on short stalks arranged at intervals along a central axis. Examine a flower and make out six dull-red leaves—the three outer ones being sepals, and the three inner ones petals—six stamens surmounted by

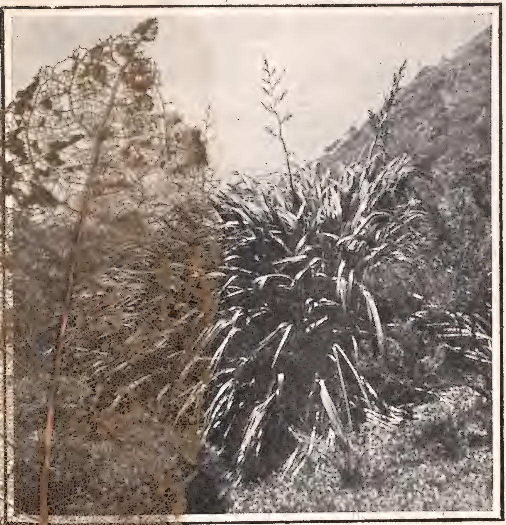

Fig. 65.—New Zealand Flax.

six conspicuous anthers, and a three-angled style ending in a three-lobed stigma. Notice that the base of the flower secretes a quantity of sweet nectar. The flowers are constantly visited by birds, attracted by this nectar, and in this way are cross-fertilised.

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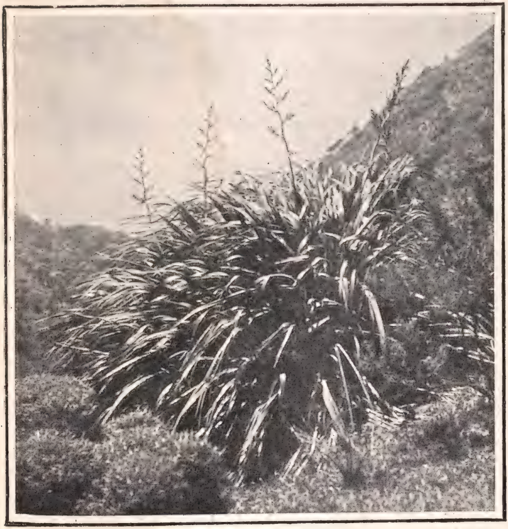


Fig. 65.—New Zealand Flax.

Cut down through the stigma and ascertain that it leads to an ovary in which the ovules may be plainly seen. There will be no difficulty in finding well-formed fruit on the same flower-cluster. Notice that this consists of an elongated three-angled capsule. Cut the capsule across and observe the three cells in which the seeds are packed. The great number of closely packed seeds are best seen in the ripened fruit.

The **Leaf.** Examine a leaf. Notice the sword-like shape with pointed apex, and the thick keel or mid-rib extending from end to end. Observe the lighter colour of the under surface, the reddish margin, the red stripe on the under surface marking the position of the mid-rib, and the parallel venation of the blade. Compare the venation with that of the Iris or Flag-lily, the Gladiolus and the common Cabbage Tree (*Cordylene Australis*), all of which belong to the same natural order of plants as the native flax.

Scrape the surface of the leaf with a knife-blade, gradually removing the soft green spongy tissue both above and below, and observe the light-yellow fibres underneath. Test for strength and ascertain that these will resist a strong pull, especially when twisted. Notice how easily the leaf can be split if torn lengthwise, and the difficulty of tearing it across. Elicit that the fibres run in the direction of the length of the leaf—also the use of the fibre—for making rope and twine.

The formation of the fibre is very like that of the Manilla hemp; but it is much coarser than the fibre of Russian hemp, or of that of the Dutch or Irish flax.

Propagation. The best and easiest way to propagate the plant is to remove the young buds as soon as they are rooted, and then plant them out. If the conditions are favourable they will grow with rapidity when once established. In moist situations the young plants will yield a regular supply of leaves for cutting in about four or five years. Partly owing to the length of time required to produce the adult plant, and partly because there has been a plentiful supply of the flax growing wild, the plant has not been more extensively cultivated. Hitherto the supply of leaves for the mills has been derived almost entirely from natural fields.

Of late years the demand for the fibre and hence the price obtained has risen to such an extent that planting operations on a large scale are now being undertaken in several districts. No doubt if these prove successful the cultivation of Phormium will become an extensive industry.

Preparation. After being cut the flax is taken to the mills, where the leaves are first stripped by revolving rollers fitted with projecting beaters. These are so arranged that the skin and loose spongy tissue are crushed against a plate, in such a way as to let the fibre pass through uninjured. After this it is well washed and spread out to dry and bleach, and finally scutched and packed in bales for market. The best fibre for rope-making is obtained from leaves about fifteen months old; for the manufacture of finer fibres that of younger leaves is preferred.

Phormium is largely used in all the colonies for the manufacture of ropes and twine, and considerable quantities are exported to England and the United States for the same purpose. Possessing so many excellent qualities the Phormium is one of the most valuable of the native plants, and bids fair to hold a permanent place among the best materials for cordage which have yet been discovered.

XX.—FUNGI.

The Mushroom. The Mushroom is a common plant in many of our meadows in the autumn, or indeed in summer, if the season be damp. The plant consists of a stout **stalk**, which rises above the ground three or four inches and bears at its upper end a circular **cap** convex above and roughly concave on its lower surface. The base of the stalk ends in a mass of white threads which spread out into the soil for a short distance. About half way up the stalk is a ragged fringe of tissue, the **collar**. This ring is the remains of a membrane which in the younger stages of the plant's growth reached from the stalk to the edge of the cap and completely enclosed its under surface. As the stalk increased in length, the membrane was torn away from the cap and left as the ring just described.

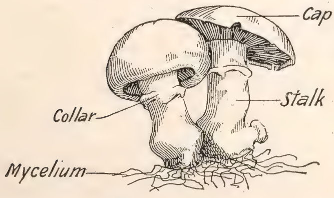


Fig. 66.—Mushrooms.

Both the cap and stalk consist of a white fleshy substance, really a closely packed mass of threads similar to those seen at the base of the stalk. On the under side of the cap are a number of radiating plates—the **gills**. These at first pink in colour, become dark brown or almost black as the plant grows older. Each gill contains a large **number of spores**, from the germination of which the plants are produced. If the cap of a Mushroom be placed on a sheet of paper so that the gills are underneath, and allowed to remain for a few days, the spores can be obtained and their position in the plant traced. The pattern on the paper will take the form of radiating lines of brown dust which evidently indicate the position and direction of the gills. The dust is composed entirely of spores, and, as these are extremely minute, care should be taken when performing the experiment to cover up the plant in such a way as to protect it from draughts, which would easily spoil the "spore print."

The net-work of threads (the **mycelium**) spreading out into the ground enables the plant to absorb food from the soil. Unlike other plants we have learnt about, the mushroom has no green leaves, hence is unable to obtain and decompose the carbon-dioxide of the air, or to manufacture food material. The whole of the food required by the plant is obtained by the underground mycelium. The use of the upper parts being confined to producing and scattering the spores. The Mushroom in fact lives on the carbonaceous food prepared by other plants or contained in animal remains, and hence can grow only in soil containing decaying animal or vegetable matter. This inability to manufacture food for themselves is characteristic of that class of plants called Fungi, to which the Mushroom belongs.

Mildew. The air, even on the finest day, contains a considerable quantity of solid particles which float about in it and are carried in all directions by the wind. Amongst these are great numbers of very fine spores, which only wait for a favourable opportunity to germinate and grow. If a piece of bread or leather be left exposed to damp air for a few days it will become covered with a woolly growth known as "blue-mould." The air is full of the fine spores of this plant which readily grow on the damp surface of decaying organic matter—such as that presented by the bread or the leather. If the conditions be favourable, the woolly growth may reach the height of an inch or more, and on examination will be found to consist of fine white threads many of which bear at their ends a small dark knob containing spores. The bursting of these knobs scatters the spores into the air where they float about as detailed above. Like the Mushroom, these moulds do not contain the chlorophyll possessed by the higher plants, and hence are dependent on other plants and on animals for a supply of organic matter.

NOTE.—There is no reason why lessons on the Mushroom should not claim attention in the Infant Department. The teaching here, however, must be very simple, and should attempt nothing more than a general description in exceedingly simple language of the plant itself. Such details as those dealing with the food supply and the production of spores, belong to the more advanced stages of a Nature-study course.

PART II.

ANIMAL LIFE.

I.—INTRODUCTION AND CLASSIFICATION.

All natural objects can be classed under two heads, the animate and the inanimate. To the former belong animals and plants, and to the latter rocks and minerals.

Animate nature is divided into two main groups, called **kingdoms**—the **animal** and the **vegetable**—and these are again subdivided into smaller and smaller groups.

The animal kingdom consists of a number of sub-kingdoms, each of which is again composed of smaller divisions or congregations of life called **classes**, though the sub-kingdom may be split up into an intermediate group of **sub-branches.** The classes are composed of **orders**, the orders of **families**, the families of **genera**, the genera of **species**, and the species of **varieties.**

In the outline given below, two of the sub-kingdoms, *viz.*, Protozoa and Molluscoidea, have been omitted, as in the following pages no mention is made of animals belonging to these sub-divisions, and as, moreover, they comprise life-forms not likely to engage the attention of the Nature-study student in our primary schools.

OUTLINE CLASSIFICATION OF ANIMAL KINGDOM.

Sub-Kingdoms.

a - - Coelenterata

- Porifera (sponges)
- Cnidaria (corals)

b - - - Echinodermata (sea-urchins, star-fish)

c - - - - Vermes (worms)

d - - - - Mollusca (snails, shell-fish)

e - - - Arthropoda

- Branchiata
  - Crustacea (crabs, etc.)
- Tracheata
  - Myriopoda (centipedes, etc.)
  - Arachnida (spiders)
  - Insecta (insects)

f - - Vertebrata

- Pisces (fish)
- Amphibia (frogs, etc.)
- Reptilia (lizards, etc.)
- Aves (birds)
- Mammalia (rabbits, etc.)

From the foregoing it will be seen that the following sub-kingdoms are referred to :—

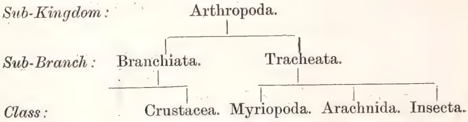
(a) Cœlenterata, comprising Sponges and Corals.

(b) Echinodermata, comprising Sea-Urchins and Starfish.

(c) Vermes or Worms.

(d) Mollusca, including Snails and Shellfish.

(e) Arthropoda, or animals whose bodies are furnished with jointed appendages. The Arthropoda are divided into two sub-branches, *viz.*, Branchiata, or those which breathe by means of gills, and Tracheata, or those which breathe by means of tracheæ or air-tubes. The former (Branchiata) are again divided into two classes, one of which, the Crustacea, includes Crabs, Crayfish, etc. The latter (Tracheata) are divided into three classes, *viz.*, Myriopoda (centipedes and millepedes), Arachnida (spiders), and Insecta (insects).



(f) Vertebrata, divided into the following classes :—

(1) Pisces (fish).
(2) Amphibia (frogs, etc.)
(3) Reptilia (lizards, etc.)
(4) Aves (birds).
(5) Mammalia (rabbits, etc.)

The student will have a clearer idea of this classification, which has been made as simple as possible, by considering the place in the animal kingdom occupied by each of the following life-forms :—

(1) The honey-bee (Apis mellifica).

Sub-kingdom	Arthropoda
Sub-branch	Tracheata
Class	Insecta
Order	Hymenoptera
Family	Apidæ
Genus	Apis
Species	Apis mellifica

(2) The rabbit (Lepus cunicula).

Sub-kingdom	Vertebrata
Class	Mammalia
Order	Rodentia
Family	Leporidae
Genus	Lepus
Species	Lepus cunicula

The table on p. 94 gives only a few of the divisions of the animal kingdom; for a more complete account the student will have to consult some work on Natural History, *eg.*, Cassell's *Concise Natural History* (Wright). It is not intended that these divisions are to be taught to children; indeed, such a procedure could only have the effect of confusing the child. They may, however, prove helpful to teachers, by enabling them to distinguish more clearly the special place in the animal world occupied by the life-form under review.

NOTE.—It may be worth while to repeat here what has already been said, that the classification of the Animal Kingdom given at the beginning of this chapter is for the guidance of teachers only, and should be drawn on very gradually, as the courses of lessons progress. To require children, especially young children, to appreciate the difference between sub-kingdoms, classes, and orders, or to discuss the considerations which enter into the placing of, say a sponge amongst the cœlenterates, would be to make demands on youthful intelligence which could result only in disaster. It is not to be supposed, however, that all reference to classification should be avoided—as pupils grow older and the courses advance, the more obvious reasons why certain animals possessing common characteristics, are included in classes or orders, or those differing in certain essentials are placed in distinct groups, should certainly be made clear. There will be no difficulty in this ; the absence of a backbone will be sufficient to show that Earthworms are not reptiles, and the threefold division of the body with the thorax carrying the appendages will serve to mark off the insect from other allied forms. All this children can readily understand and follow, and should be taught to recognise and interpret. Consideration of the kind, however, should not be attempted in the earlier stage, but be deferred until pupils have become more familiar with the characteristics they are called on to observe. In the Infant Department certainly, and in SI perhaps, children will have done enough if they observe these characteristics, learn to contrast and compare them, and to find suitable verbal expression for the result of their investigations. It is in the further expansion of the subject to be undertaken in the higher classes when the intelligence of the pupils is better fitted to cope with and overcome difficulties, that classification can best be introduced—but at no time should the teaching aim at instruction in what is known as *Natural Science.* To quote from the English code, and applying to Nature-study what is there said under the head of "object teaching." "It is elementary science only in so far as it aids the child to observe some of the facts on which Natural Science is founded ; but, as it deals with such topics generally, it differs widely from the systematic study of a particular science. The principles of scientific classification, the continuous study of one group of natural phenomena, the generalisation from facts and the search for natural laws, belong to a later stage of mental discipline, which will be much more effectual if it is founded upon the preliminary training of the senses through sound object teaching." The primary aim of Nature-study should never be lost sight of, viz., to train pupils to observe and understand the more obvious of the natural laws at work around—to lead them to derive real pleasure as well as profit from the occupation itself—and gradually to acquire the habit of applying contrast, comparison, experiment, trial, in unravelling the difficulties that beset them.

Reference has been made in the preface to the use of technical terms, so that little need be added here—further than to remind teachers of the need for introducing them slowly and only when and where required. If a popular name answers the purpose, it is the reverse of wise to make use of its scientific equivalent—nothing will be gained for instance by speaking of the leaf-stalk as the *petiole*, or the thigh-bone as the *femur*. It is only when popular phraseology can furnish no equivalent, as in the case of the essential organs of the flower, stamens, pistil, etc., or, where it fails in accuracy of expression, or where the scientific name is terse, pointed, and easily remembered that it (the technical or scientific term) should be employed.

II.—A SPONGE.

The common sponge belongs to a division of the sub-kingdom Cœlenterata, known as **Porifera,** or animals whose bodies are traversed by canals which open to the surface and are connected with a central cavity.

That a sponge is a porous substance is easily demonstrated to a class; one has only to place it in a vessel containing water, and require pupils to observe the disappearance of some of the liquid when the sponge has been removed. The sponge moreover is yellow in colour, light, elastic, tough and soft—properties which make it extremely useful for washing purposes. A closer examination of the sponge will show that it is composed of a vast number of tiny threads closely interwoven—it is the space between these which forms the pores so useful in absorbing and retaining water. There are also a number of larger openings leading inwards. These, however, retain but little water, as can be easily shown by holding up a saturated sponge and allowing the liquid to drain away—this it does through the large openings. If we wish to remove the water from the smaller spaces, we must squeeze the sponge.

The substance of which the sponge is composed is silky in nature—hence its strength and softness. The silky nature of the material would suggest its animal origin, for we know that silk is an animal product being made by certain kinds of insects and by spiders. Sponges were originally regarded as belonging to the vegetable kingdom, but are now universally admitted to be animals, though unlike most animals we are acquainted with, they are unable to move about.

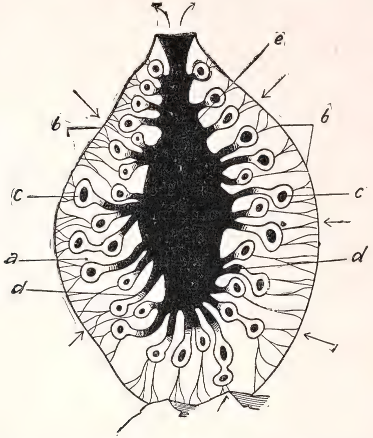


Fig. 67.—Structure of common Sponge diagrammatically represented.
a, sponge-flesh; *b*, pores opening into canals; *c*, ciliated chambers; *d*, large exhalent canals; *e*, central cavity. The canal system is black, and the course of the water-currents is indicated by arrow heads.

The sponge as we have seen is composed of a fibrous substance in which are numerous rounded chambers. These are connected with the outer surface by a network of pores, and with the large inner cavity or cavities by a system of canals. The water containing a food supply with the dissolved oxygen which the animal requires, enters through the pores, flows into the chambers along the passages, and through the central cavity from which it is finally discharged. The flow of the water through these passages is brought about by the whip-like ciliae which grow from the walls of the chambers, and are continually lashing the water and so driving it forward. As the water moves along the passages which ramify in all directions, the animal is able to absorb the nutritious matter it contains, as well as obtain a supply of dissolved oxygen. The sponge is continually in need of nourishment, hence the necessity of the constant flow of water through the channels, and hence therefore, the importance, indeed actual need, of the incessant movement of the ciliae. It will be noticed that the pores through which the water enters are much smaller than the canals along which it subsequently flows, an arrangement which prevents the blocking up or choking of these minute external openings.

When the sponge is first obtained, it is covered with a soft living jelly very like the white of an egg. This is the flesh which is supported on that part of the animal which we call the skeleton. The common sponge so constantly in use in our homes may therefore be described as the skeleton of a marine animal. Part of the jelly drains away as soon as the animal is removed from the water; the rest is got rid of by squeezing and wringing, by stamping underfoot, or by pounding with wooden mallets. After this the sponges are thoroughly dried in the air, and further cleaned and bleached; they are then ready for the market. The common sponge grows in warm seas—great quantities being obtained from the Mediterranean and considerable numbers round the Australian coasts. It is found attached to hard firm objects, such as rocks. If the water be deep, divers are employed—if, however, it be sufficiently shallow, the sponges are cut from the rocks by means of hooks attached to long poles. Certain kinds of sponges are not uncommon along the New Zealand coasts. These, however, are hard and brittle and generally lacking in those qualities which make the common sponge so useful.

NOTE.—This subject might be taken in any of the classes. The physical properties of the sponge form a suitable topic for investigation either in the Infant Department or St. I., where its lightness, elasticity, porosity etc. could be discussed. The investigation of the last-mentioned property, viz. porosity, would lead incidentally to a talk on porous bodies—blotting paper, chalk, lamp-wick, charcoal etc. The animal origin of the sponge can be inferred from the nature of the material composing it; for it consists of silky fibres, and do not Silk-worms and Spiders spin silk? Several kinds of sponge are found along the New Zealand coast—these when available should be utilised in determining the marine origin of the animal and in other parts of the lessons.

The whole of the lesson or lessons should be plentifully illustrated by drawings and diagrams, especially those parts dealing with the living sponge, its growth and development, method of procuring food, as also the way in which sponges of commerce are obtained, though much of this part of the subject might be held over until pupils have reached the standard classes.

Sea-Anemones and other forms belonging to the coelenterates could also be profitably studied in suitable localities. In the rock pools along many parts of the coast Sea-Anemones abound; some of the forms being exceedingly beautiful and reaching upwards of six inches in diameter when expanded. Any investigation of the Sea-Anemone should be undertaken out of doors, when the animal could be observed under normal conditions. During an excursion made to the rock-pools, other water dwellers could be studied.

III.—THE SEA-URCHIN.

The common Sea-urchin, or sea-egg, found in abundance in the rock-pools along our coasts, belongs to the sub-kingdom known as Echinoderms, which includes Star-fish, Sea-cucumbers, and other allied forms.

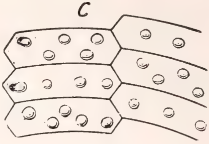
It lives in the rock pools, and feeds on the minute forms of animal life with which these abound.

The body of the animal is protected by a hard disc-like shell, convex above and flattened and slightly concave below. The surface of the shell is covered with a number of movable **spines** carried on small rounded elevations. On the under surface is an opening (the mouth) through which the teeth can be thrust. The **teeth,** five in number, are packed closely together, and present a sharp beak-like appearance.

If the animal with its shell covering be buried in sand or in the ground for some time, the spines will drop off and the soft parts will disappear; the shell can then be examined more closely.

In its living state the spine-covered test is dark in colour, but, when prepared for examination as described, the colour changes to light green, or reddish brown. The elevations on which the spines are supported are plainly visible, radiating from a small circular area on the upper surface of the test.

If held up to the light and looked at through the opening on the lower side, the perforations in the shell can be easily made out; these will be found to occur along definite areas. The outer surface of the shell shows five well-marked *perforated areas*, wedge-shaped at either end, and lying between these five similarly shaped spaces where *no* perforations occur. Through these minute openings the animal is able to thrust out numerous small tubes, each of which is capped by a calcareous plate. A system of water-vessels with which it is provided enables the animal to force water into these tubes (tube-feet), and utilize them for purposes of locomotion. The five longitudinal areas bearing perforations are raised above the fine intermediate areas. If the shell be broken it will be found to consist of a number of calcareous plates usually five-sided immovably connected together.



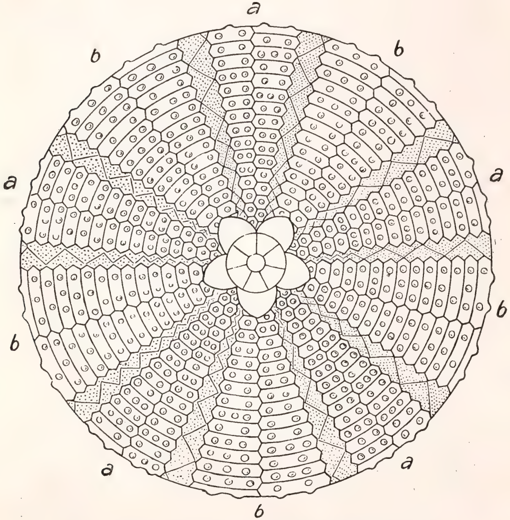


Fig. 68.—Test of Echinus viewed from above.
a, perforate areas; *b*, imperforate areas; *c*, plates of which test is composed.

In the Star-fish the central disc gives off a number of radiating arms. On the under surface of these are perforated grooves, from which tube-feet protrude. The mouth, too, is on the under surface of the body, but there are no teeth.

NOTE.—In examining this form pupils should if possible be taken to a rock pool where the animals could be seen. If this cannot be done, a test with the spines attached should, if possible, be secured, and an examination of this should precede that of an empty test with spines removed. Such a test is best prepared by burying the animal in the ground or allowing it to remain in fresh water for some weeks, when the body tissue will gradually disappear without injuring the hard outer covering.

There will be no difficulty in following the description given in this chapter and in making out the perforate and imperforate areas. The immovable calcareous plates can easily be seen if the test be broken — as it will naturally separate into these five-sided plates. The **sutures** or lines of division will appear in well marked ridges on the under surface of the test.

It is hardly necessary to say that pupils should make their observations from actually handling the object. The position and number of the different areas, direction of sutures, size and shape of plates etc. ought to be determined by each pupil at first hand.

The habits—method of locomotion etc. should be observed out-of-doors—that is, during a visit to the natural habitat of the animal, when opportunities would no doubt occur for examining specimens of Star-fish as well. A contrast and comparison between the two forms would be both interesting and instructive.

IV.—THE EARTHWORM.

The Earthworms belong to the sub-kingdom **vermes** which includes **sea-worms** and **leeches.**

Though elongated like a snake, and cold and clammy to the touch like a frog, pupils will readily see that the common earthworm belongs to neither of the divisions of the animal kingdom which include these forms, in that its body, which is soft, is *without a backbone.*

General Description. In shape the worm is long and roughly cylindrical, though slightly flattened on the under surface. Its body is made up of a large number of segments or rings which can be easily made to contract or expand. One end of the body is more pointed than the other—it is here that the head is situated, with the mouth in the first segment. The skin is kept moist and slimy by numerous glands which pour out mucus, and so prevent too rapid evaporation of moisture. It is of the utmost importance that the skin remains moist. Earthworms have neither lungs nor gills but obtain a supply of air

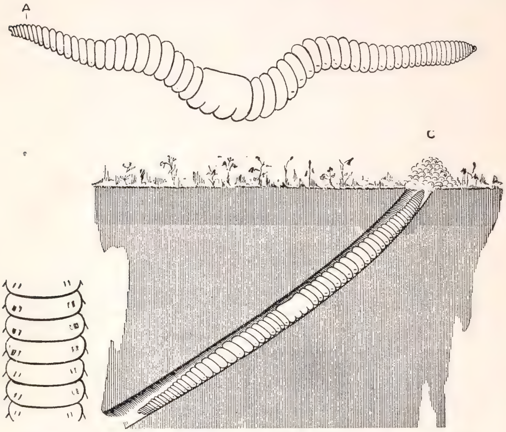


Fig. 69.—*A*, Head of Earthworm. *B*, Section of Body showing Segments carrying Bristles. *C*, Burrowing Worm and Castings.

through the skin—as frogs do when under water. It is for this reason that Worms are nocturnal in their habits, and quickly die if exposed to a strong sun. The hot sun dries up the moisture on the skin and so the air is unable to pass through and supply the blood with oxygen.

Locomotion. The rings of which the body is composed can be compressed and lengthened, or widened and shortened by means of special muscles. This has the effect of elongating or shortening the body, and so of enabling the animal to crawl along. Its power of locomotion is greatly assisted by short bristles carried by the segments. The bristles are directed backward, and as the body is elongated they move over the ground without catching, but firmly fix the fore part when the body begins to contract, the net result being a forward movement. On all the segments except those in front, there are four pairs of these bristles *(setae)*, two pairs on the under surface, and one pair at either side.

Burrowing. Worms burrow in the soil, the shape of the body being specially fitted for this purpose. When about to burrow the worm elongates the fore part of its body which becomes thin and pointed. It then feels about until it finds a crevice in the soil into which it thrusts the pointed head. The operation of dragging itself into the burrow causes the body to shorten and thicken and so widens the opening. If the soil be too compact to burrow in, the animal gnaws its way along swallowing the earth, most of which passes through its body and is delivered at the surface in the form of worm-castings. The mucus poured out on the skin, by making it slimy and hence reducing friction, enables the animal to move through the soil with much greater ease.

Senses. The Worm is without the sense of hearing, and has but little sense of sight. Its sense of feeling, however, is very highly developed, the slightest jarring or movement of the soil being instantly felt.

Food. Worms live on decaying vegetable matter; some of this is obtained from the earth swallowed in burrowing; but most of it is procured from leaves and other parts of plants which are dragged into the burrows. It is at night the animal searches for food on the surface of the ground. The fore part of the body is then forced out, the tail being generally fixed in the burrow to admit of instantaneous retreat in case of danger.

Uses. Small as these animals are, they do exceedingly useful work, the extent of which is made possible by the immense numbers in which they exist. According to some writers, these reach from fifty to sixty thousand per acre. The worms swallow the soil in large quantities and extract from it the nutritious portions. The rest, which becomes even more finely divided in its passage through the animal, is deposited at the surface in the form of castings. Darwin estimated that in this way about fifteen tons per acre were annually brought up and spread over the ground. Mr. A. Millson, as the result of numerous experiments in W. Africa, calculated that 62,233 tons of subsoil were brought to the surface each year over every square mile of ground. The leaves and other decaying vegetable matter dragged into the burrows help to enrich the soil, and the openings formed by their passages through the ground give access to the air from above, and furnish drainage channels for water which otherwise would be unable to get away.

NOTE.—In examining small animals like the Earthworm it is not at all necessary that each pupil should be provided with an unfortunate specimen, which could not fail to be more or less injured, perhaps mutilated, during the process of investigation. Where classes are small, a shallow box containing a few inches of earth will serve as a suitable receptacle for the animals. Around this the class could be grouped in such a way that pupils would be sufficiently close for accurate observation. In larger classes some specimens in test tubes might be passed round, and a few of the pupils called to the front from time to time to help in the investigation.

Like most of the other lessons—this one can be taken up at any stage, though, if it be dealt with during the earlier part of the course, it should receive very simple treatment. It seems better to defer it until the pupils have reached SII or SIII, when the investigation would be more likely to evoke interest, and would be better understood. The younger children for instance would find much difficulty in appreciating the purposes served by a moist skin, or the uses of the animal as a benefactor of mankind.

The method of locomotion and burrowing can be learnt from observation if the worms be placed in a box of earth as suggested, and a few judicious questions will elicit why the animal is nocturnal and avoids the sun. To see the worm feeding pupils would have to make observations on their own account at nights. This again could be better undertaken by the older pupils. The animals' sense of touch, hearing, etc., can be made the subject of interesting experiments. The clapping of one's hands or the striking together of two pieces of wood does not disturb them, from which we conclude they are deaf. A bright light suddenly introduced into a previously dark room causes them to shrink back into their burrows : having no eyes we infer they are blind, but for all that they must be sensitive to light. If the box in which they are placed be tapped, even gently, they at once set about retreating to their burrows—that is they feel the smallest vibration or have a very keen sense of touch. The food is no doubt discovered mainly by sense of smell which must be very highly developed.

The Earthworm is one of the best subjects for bringing home to children the great importance of apparently insignificant creatures and serves, moreover, to bring into contact with many useful details those pupils who will afterwards be taking up courses of agriculture, or who are already engaged in that work.

V.—MOLLUSCS.

Introduction.—Molluscs are soft-bodied animals, many of which secrete a hard protective covering called a shell. A few are air-breathers like the Garden Snail; but most of them obtain a supply of oxygen by means of gills.

The molluscs may be divided into two main sections distinguished by the presence or absence of a distinctly marked head. The forms having a head correspond to those whose shells consist of a single valve, whilst the headless forms are distinguished by the possession of a bi-valve shell. To the former belong the **Gastropods** (Snail, etc.), and to the latter the **Lamellebranchs,** (Oysters, Mussels, etc).

Land Molluscs.

The Snail. The Garden Snail is a pulmonary or air-breathing Gastropod. The shell is in one piece, spirally coiled, and consists of a number of **whorls.** The portion of the shell in which the animal lives, is known as the **body-whorl,** whilst the rest of the shell is called the **spire.** As the animal grows larger, the body whorl increases in size by additions made to its aperture.

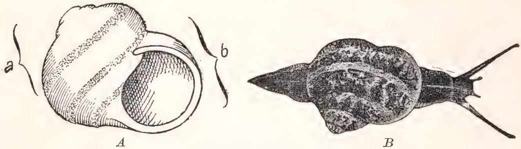


Fig. 70.—*A*, Shell of Garden Snail.
a, spire; *b*, body whorl.
B, Garden Snail withdrawn from Shell and crawling along.

The snail has a well marked head, which bears in front two pairs of retractile **tentacles** or **horns.** The tips of the upper pair, which are longer and thicker than the lower pair, are furnished with **eyes,** *i.e.*, there is an eye at the tip of each of the upper horns. As the horns are retractile the eye can at any time be withdrawn from danger.

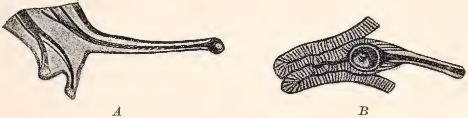


Fig. 71.—Section of Horn, showing Eye.
A, Eye extended. *B*, Eye withdrawn.

The lower surface of the body is known as the **foot**—it is strong and muscular, and on it the animal crawls along. The food of the Snail consists of young tender leaves; these it is able to strip off the plants by means of its tongue, which is furnished with rough tooth-like projections. Its mouth is situated below the smaller pair of horns.

The Snail is a land mollusc and an air-breather. The **mantle fold** under the shell encloses a lung cavity in the walls of which are numerous blood vessels. The opening leading to the lung cavity and known as the **respiratory pore,** is placed on the right side. During the winter months the Snail remains in a torpid condition under stones and logs or along the bottom of fences in places of shelter.

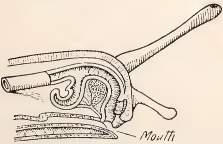


Fig. 72.—Section of Snail's Head.

The Slugs which are so plentiful and destructive in our gardens are almost identical in structure—unlike the Snail, however, they do not possess tentacles or horns, and the shell is not visible, being hidden in a fold of the mantle.

Marine Molluscs.

Although land molluscs are by no means uncommon, it is the marine forms which are most plentiful and best known. They occur everywhere along our coasts, and in certain special localities are found in great numbers and variety. It is in the study of marine shells that children will probably display most interest, and it is by means of these that they will most readily grasp the idea of the two main divisions of molluscs—univalves and bivalves.

Univalves. Beginning with the univalves, a good form to study is **turbo**, found in considerable numbers along rocky or boulder-strewn coasts. In size the shell varies a good deal, some of the larger specimens being upwards of two inches in height. In colour the shell is almost black, but after being kept for some time it changes to a reddish brown. It consists of a large body-whorl, and a relatively short spire. The mouth of the shell is circular, and the lip **whole** or **entire**. When disturbed the animal withdraws into its shell, the mouth of which is closed by a solid calcareous plate (the **operculum** or gill-cover) attached to the extremity of the foot. The operculum is smooth, bright green in colour, and, being easily polished, is sometimes used in making ornaments of various kinds.

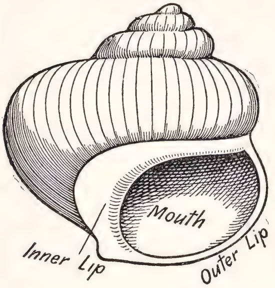


Fig. 73.—Turbo Smaragdus.

If a few drops of hydrochloric acid be poured on the shell the effervescence caused will show that it consists of carbonate of lime.

Voluta pacifica is another suitable form for study. The shell, which is thick and strong, has a smooth polished surface. In some forms a row of short projections runs along the upper whorls, gradually disappearing as the apex is reached. The body whorl is long, and surmounted by a short spire. The mouth is long and oval. The outer lip is broken on its lower margin by a shallow notch through which the tube or siphon which conducts the water to the gills passes. The inner lip along the columella or axis of the shell shews a number of spiral folds. A few drops of hydrocholoric acid poured on the surface will shew that, like the other shells described, it consists of carbonate of lime.

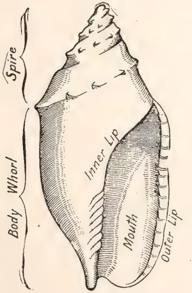


Fig. 74.—Voluta Pacifica.

A comparison and contrast. An examination of these two forms will show that each consists of a thick strong single shell, spirally coiled, and composed of carbonate of lime. The strength of the shells will suggest their habitat—in rock-pools and amongst boulders where they are constantly dashed about by the waves. Each shell is the product of a marine animal, and consists of a body whorl and a spire. The shells differ in the shape of the mouth in the nature of the lip, in the size of the body whorl relative to that of the spire, in the markings on the surface, and in other minor details.

Bivalves. Bivalve Molluscs, as their name implies, have their softer parts enclosed in a shell consisting of two pieces—a right and a left **valve,** which in most forms are equal and similar. The valves are attached to each other along the back (*a*) by an elastic **ligament**; and (*b*) by muscles and connective tissue, which pass from the inner surface of one valve to the inner surface of the other. The elastic ligament may be **outside** the shell, in which case it extends from one valve to the other just behind the **beak** in such a way as to be tightly stretched when the shell is closed; or it may be **inside** the shell placed between the hinge-lines of the two valves, perpendicular to the surface on which it rests. The closing of the valves is effected by the contraction of powerful muscles, known as **adductor** muscles which, as previously stated, pass from one surface to the other—whilst the opening is brought about by the elastic force of the ligament. When the animal wishes to open the shell, it has only to relax the adductor muscles, whereupon the elastic force of the ligament is sufficient to force the valves apart.

The union of the valves is still further strengthened in most shells by means of a series of parts called **teeth,** which interlock with one another (see fig. 75).

The animal lives on the small particles of nutrient matter brought to the mouth by ingoing currents of water, which pass over the gills and through the digestive tract. The currents of water may find their way to the mouth cavity direct, or may enter and leave through a siphon tube, there being one for the ingoing and another for the outgoing currents. The mantle lobes, a pair of delicate membranes, which hang down from the sides of the body, are attached to the lower inner surface of the shell.

All these organs leave well-marked impressions or scars which are plainly visible when the animal is removed from the shell, and which can be made the means of a good deal of useful and interesting investigation.

As the animal increases in size, and the shell becomes too small to cover the soft parts, additions are made to the outer margin. These, too, frequently leave well-defined markings on the outer surface.

The following are amongst the points to be noticed about the shell of a bivalve Mollusc. The top of the valve is called the **beak** (*d*) and is generally turned towards the front part of the animal. In forms where this is the case, we can readily distinguish between right and left valves, for we have only to hold the shell, with its beak pointing away from us, and the right and left valve will correspond in position with the right and left side of the body.

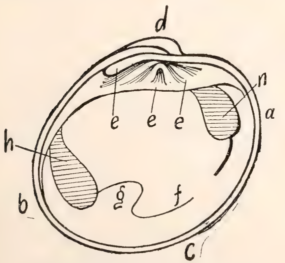


Fig. 75.—Left Valve of Mollusc.
a, front; *b*, back; *c*, lower margin; *d*, beak; *e*, teeth; *f*, pallial or mantle line; *g*, break (sinus) in mantle line; *h*, adductor muscle impressions.

That portion of the shell where the beaks are situated, and where the valves are united, is called the **dorsal** or upper side, and the opposite margin along which the shell opens is known as the **ventral** side or base. The length of a shell is measured from its front to its back margin, and its width from the dorsal margin to the base. The inside markings include the **adductor muscle impressions** and the **pallial line,** which may be entire or may contain a **sinus** or bay (see figure 75).

An examination of one or two shells will make the matter clearer.

Let us take for investigation the well-known form Venus, any species of this genus will do, and specimens are available on most of our coasts.

The shell is brown in colour, nearly spherical in shape, and marked on the outside with concentric furrows—which in the form figured are crossed by lines radiating from the beak. The beak is placed towards the front—and the ligament is on the outside of the shell, or external.

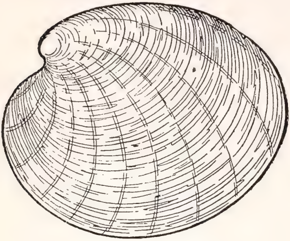


Fig. 76.—Left valve Venus (outside).

Inside, the impressions marking the attachment of the adductor muscles are plainly visible, and the pallial or mantle line is broken towards the back margin by a little opening or sinus.

The hinge line is strengthened by the presence of three teeth which fit into as many corresponding grooves, and add greatly to the force with which the valves are held together.

Another common bivalve is the Scallop (genus *Pecten*) found in considerable numbers on many of our sea beaches. In colour the shell is reddish brown, and in shape nearly circular. The valves are unequal and dissimilar, the right valve being convex and the left almost flat. The beaks are close together and eared—the ears on the right valve being most prominent. The outside of both valves is marked by a number of grooves which radiate from the beaks. In the centre of the hinge line (which is straight and without teeth) and below the beak, is a triangular depression. This holds the ligament, which, unlike that of Venus, is inside the shell, is in fact **internal.** The pallial line is simple, which shows that the animal does not possess siphons—and there is only one adductor muscle impression.

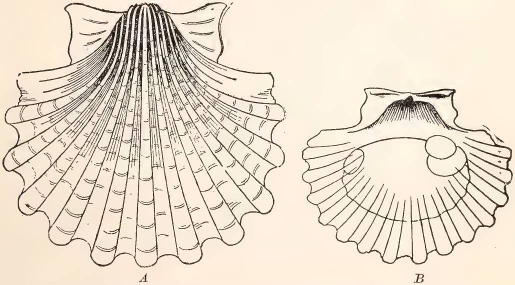


Fig. 77.--Right valve Pecten. *A*, Outside surface. *B*, Inside markings.

The forms to be dealt with will depend to a large extent on the locality of the school. When a sufficient number of these have been examined, they should be contrasted and compared as in the case of the Gastropods.

NOTE.—There are hardly any natural objects in which children are more interested than shells, or any indeed which furnish better opportunities for developing the faculty of accurate observation. For these reasons they form splendid material for lessons in all classes; besides, the method of treatment can render the subject sufficiently simple for young children, or difficult enough to demand the concentrated attention of older pupils. The Garden Snail with a description of which the chapter begins, need not necessarily be taken first; indeed, it might with advantage be reserved for a standard class, when it could be more fully treated.

In the Infant Department the subject might begin with the two main divisions of shells—univalves and bivalves. All detailed descriptions of the animals which form and dwell in the shells might be omitted, except that they are soft-bodied and cold to the touch.

The two classes could then be dealt with separately, and in some detail, *e.g.*, the colour and form of the shells with some of the more obvious markings. From the earliest lessons comparisons and contrasts should be made where possible. When the classes are further advanced, the next step would be to select some simple form and require pupils to name the parts of the shell. Taking the univalve first—the body whorl, spire, mouth, inner and outer lip should be known. But little difficulty will be found with these terms—pupils should draw the form under review on their slates and write the names opposite the parts to which they belong. Before passing on, this part of the subject should be mastered in such a way, that on being handed a specimen, pupils should be able to apply the knowledge gained ; that is, pointing to the places indicated, they should readily name them without hesitation, *e.g.*, " This is the spire, this the body whorl, here is the mouth," etc., etc. The outside markings could then be treated in the same way. Plenty of specimens should be dealt with in these lessons.

The same remarks apply to the bivalves—the parts of the shell should be learnt first—then the markings inside and outside, the teeth, hinge-line, etc., dealt with. Some description of the animal itself, of the way in which it obtains food, of its method of enlarging the shell, and of its habits, should be incidentally given.

The amount of attention devoted to these lessons will of course depend on the surroundings of the school. A study of marine molluscs might under certain conditions be omitted altogether. Many schools removed from the sea are within reach of fresh water molluscs, *e.g.*, the fresh-water mussel unio, these would form suitable subjects for investigation. In the case of schools near the sea coast, a good deal of prominence might profitably be given to this phase of Nature-study. Pupils could be encouraged to collect and bring specimens for examination, and might from time to time be taken for excursions with the object of applying the knowledge gained, and of observing the conditions under which the animals live. The reasons why some shells are thick and strong, others thin and fragile, and many other matters of interest would then be realised in a way impossible under indoor treatment alone.

VI.—INSECTS.

INTRODUCTION.—Insects belong to the sub-kingdom *Arthropoda*, or animals furnished with jointed appendages, and to that division of it which includes those animals breathing by means of tracheæ or air-tubes.

The amount of insect-life throughout the world is prodigious—it is found in climes ranging from arctic to tropic—in dark caves, in brilliant sunshine, in water and on land. New Zealand contains a large number of insects, a few of which have been introduced. The vast majority, however, are native, having reached these shores in various ways a very long time ago. The relation of insects to flowers is one of great importance, the fertilisation of the majority of flowering plants being brought about by their agency. In other ways, also, they serve very useful purposes ; the common House Fly, for instance, by consuming scraps of organic matter, which might otherwise decay and give rise to offensive odours, perhaps to disease; and the Bee, by converting the sweet nectar of the flowers into delicious honey : ink, cochineal, and sealing wax, too, are obtained from insect products. Then, too, they constitute the *sole* food of large numbers of birds, and *some part* of the food of nearly all. On the other hand, there are many insects that do us injury. The Codlin Moth, which attacks and destroys fruit, and those insects which do so much damage to crops, are familiar examples.

An insect may be defined as a jointed animal having its body divided into three distinct regions—*viz.*, the head, the thorax, and the abdomen. It has, moroever, three pairs of legs, and generally two pairs of wings, all of which are attached to the thorax. To acquire this structure, the creature passes through several changes, termed its metamorphoses.

STRUCTURE OF TYPICAL INSECT.

The **head** shews no distinct divisions, but bears the **eyes**, the **antennæ**, and **mouth**.

The chest, or **thorax**, consists of three main divisions, to each of which is attached a single pair of **legs** ; each of the lower divisions may carry a pair of **wings**.

The **abdomen** is made up in the typical insect of eleven segments, but some of these are often wanting.

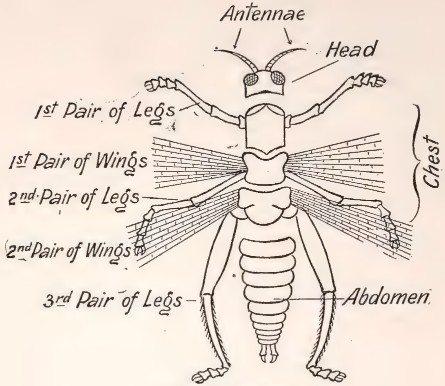


Fig. 78.—Typical insect.

USEFUL INSECTS.—THE HONEY BEE *(Apis Mellifica)*. The pupils will notice the well marked division of the body into head, thorax, and abdomen.

General Description. The head bears the antennae —two mandibles—two compound and three simple eyes, and the mouth. To the thorax, or chest, are attached on the under surface, three pairs of legs, and above these two pairs of wings. Each pair of wings is firmly hooked together—the hooks occur on the upper margin of the lower pair, and fit into folds on the lower margin of the front and upper pair. The abdomen consists of a number of rings or segments. Each entire segment is made up of two portions, an upper and a lower half, connected by an elastic membrane. Both the chest and abdomen are covered with hairs. At the lower end of the body is a sharp stabbing instrument known as the sting.

Respiration. Along the sides of the body, between the segments and half segments, are a number of small openings — the **stigmata** or **spiracles**. These are connected with larger tubes, the **tracheæ**, which run to all parts of the body. The bee has neither lungs nor gills—it breathes by means of these air-tubes. If the bee be held by the wings it will still continue to "hum," the sound being made by the air driven through the spiracles causing the rapid vibration of minute plates in these openings. From the sides of the spiracles a number of small hairs grow inwards, to prevent particles of dust from entering. This description will show why an insect dies so quickly if immersed in a sticky fluid, or exposed to the effects of a poisonous gas—in the former case the breathing holes become clogged, and in the latter the gas is rapidly drawn to every part of its body.

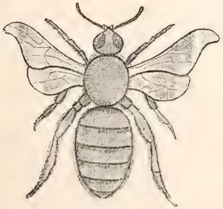


Fig. 79.—Honey Bee.

The two large compound **eyes** are easily seen—the three simple eyes are situated between these.

The two **antennae**, or feelers, which are characteristic of all insects, are carried by the front portion of the head. In these lies the organ of smell, which is so keen that Bees can not only discover the flowers from which they obtain honey, but are also enabled to recognise members of their own hive.

Gathering Food. The whole process of gathering food can and should be observed. On reaching a flower the Bee anchors itself by the claws and pad at the ends of its legs. It then thrusts into the flower its long pliant and hairy tongue, with which it licks up the nectar. This is quickly transferred to the honey-bag, where it is converted into honey, a substance differing in colour, taste, and smell from the nectar of the flower. The head also carries a pair of mandibles—these are used for detaching the pollen grains from the anthers of the flowers or the resinous propolis from certain trees—cone-bearing trees contain a plentiful supply of this substance.

The food thus obtained is carried back to the hive, where some of it is used to feed the young bees and drones, the rest being stored up for winter use. The Bee's body and legs are covered with hairs—to these the pollen grains cling when the insect brushes against them. On the inner side of the first tarsal joint there is a series of rows of stiff hairs called the **brush**; whilst on the outer side of the tibia joint is a triangular depression known as the **basket.** With the brush of the right leg the bee gathers the pollen adhering to its body into the basket on its left leg, and with that of the left leg sweeps the pollen into the basket on its right leg. The pollen and propolis detached by the mandibles are in the same way passed back and transferred to the baskets.

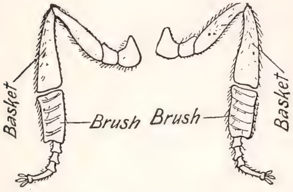


Fig. 80.

The Sting is a combination of a sharp stabbing instrument and a poison gland. The former makes the wound into which the latter pours a drop of poison, often causing pain and swelling. The irritating liquid or poison contains an **acid** ; this can be neutralised by an **alkali** ; hence, if the wound be rubbed with carbonate of soda or liquid ammonia, the pain and swelling will be relieved. The sting is a modified **ovipositor** or instrument for placing eggs in a desirable position, with which the female forms of many insects are provided.

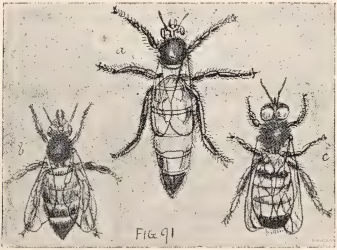


Fig. 81.—(*a*) The Queen Bee, (*b*) the Worker, (*c*) Drone Bee.

The Bee Community. There are three kinds of bees found in the hive—the **worker,** the **drone,** and the **queen** bee. The worker is the form just described, and is the one which, as its name implies, does all the work of collecting and storing the honey. The drones or male bees are easily distinguished from the workers by their longer and heavier bodies ; they do no work, and are killed by the workers before the end of the honey-collecting season. They do not possess stings, nor are their hind legs provided with the arrangements which enable the worker to carry pollen. The queen, which is longer and more slender in build than either of the other two, can also be recognised after a little practice, but she seldom leaves the hive, and hence is not often seen. She lives about four years, and during that time lays many thousands of eggs.

Storage of food. Unlike most insects, Bees live through the winter, and as at that time of the year but few plants are in blossom, it is necessary that they provide themselves with a supply of food beforehand. This they do, storing it up in the honey-comb, consisting of specially constructed air-tight cells, closed at the top by tightly fitting lids of wax. The comb is made of wax which is formed from honey, and which oozes out between the joints of the body segments. In order to obtain the wax a number of insects hang in a cluster for some time, when the warmth of the cluster causes the wax to ooze out as already stated.

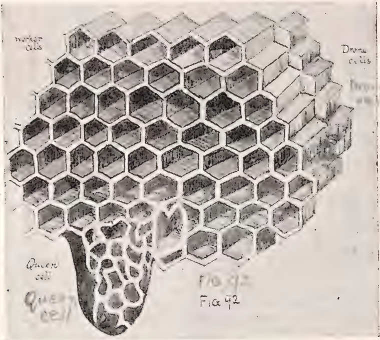


Fig. 82.—Cells of the Hive-bee, showing Queen Cell, Worker Cells, and Drone Cells.

The cells of which the comb consists are six-sided, and arranged on either side of a central plate. They are used not only for storing food, but also as compartments in which the young are reared.

The **brood cells** are not all the same size, some being considerably larger and longer than others. As soon as the nursery cells are complete, the queen begins to lay her eggs, depositing one in each cell. An eyeless grub or **larva** hatches out in a few days, and immediately begins to devour the food which has been left for its use. It grows very rapidly and soon fills the entire cell, which in the meantime has been sealed up by the bees. It next surrounds itself with a silken web and changes into a **pupa** or chrysalis, from which in a short time a fully grown and fully developed Bee emerges. This change from the pupa stage into the fully developed form is characteristic of all insects.

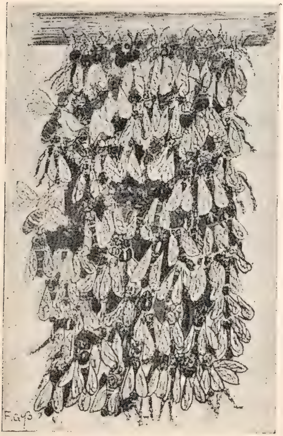


Fig. 83.—Bees forming Wax.

In other larger cells either drones or queen bees are produced—those from which the former come are called **drone** cells, and those which produce the latter are known as **royal** cells. It is difficult to understand why the eggs, which, so far as is known, are all exactly alike, should develop into forms so entirely different. The difference is said to be due to the food on which the larvæ are reared.

Swarming. The hive contains only one queen. So soon as a new queen emerges from a royal cell, the old queen, accompanied by a swarm of workers, quits the hive. After flying about for a short time these settle on a suitable branch, and hang down in a long cluster. Keepers of bees are always on the look out for "swarms" of this kind, which are transferred into other hives, where they in turn increase in numbers and send forth fresh colonies. It sometimes happens—especially at the end of the season, or if the numbers in the hive be small—that the queens are stung to death as soon as they appear.

Uses. Though insects as a whole serve a number of useful purposes, those that are directly serviceable to man are few, and of these the Honey-bee comes first in importance.

As direct products of its industry we get honey and wax, whilst the fertilisation of flowers which is brought about by its labours is of great practical importance.

The Silk Worm.

Another useful insect is the moth of the Silk-worm; and as it is easily obtained and easily kept, its life-history can be readily observed.

The Silk-worm moth is about 1½ inches in expanse of wings. Its body, which is thick and hairy, shows the three-fold division characteristic of insects. The thorax carries three pairs of legs and two pairs of white wings, streaked with dark bands. In front of its head are a short **proboscis,** and two feathery feelers, which, unlike those of the butterfly, *are not clubbed.*

The female moth is larger than the male. She lays from 200 to 400 eggs, usually on the leaves of mulberry trees on which the larvæ feed. In a short time the egg develops into a larva or caterpillar (see fig. 86). The caterpillar is small at first but rapidly grows in size, consuming large quantities of food, and sometimes reaching upwards of three inches in length. During the process of growth its skin becomes too small and is cast. This casting of the skin is characteristic of all larvæ—in the case of the Silk-worm four new skins are formed and as many old ones cast during the larval stage, which lasts from six to eight weeks. Pupils will notice the form of the larva. Its head is small, hard, and reddish-black in colour. Its body is light grey, and made up, to all appearance, of twelve segments (there are really thirteen, but the last is only obscurely indicated), of which the last

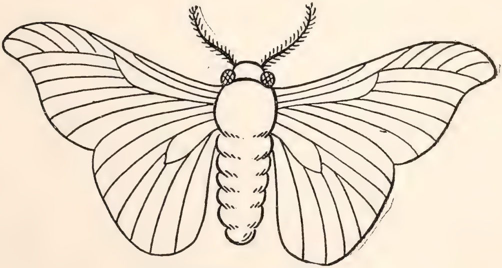


Fig. 84.—Silkworm Moth (female)

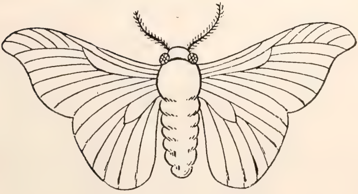


Fig. 85.—Silkworm Moth (male).

but one carries a horn; on the under surface are sixteen legs—three pairs of jointed legs in front, as in the larvæ of all insects—and five pairs of unjointed fleshy legs behind. The three pairs in front end in sharp points, whilst the first four pairs on the abdominal segments are armed at their base with a circle of hooks; these enable the animal to hold on to the surface of the objects over which it is climbing.

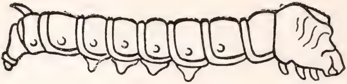


Fig. 86.—Silkworm.

When full grown the larva sends out from two holes below the mouth a fine yellow sticky substance, which hardens on being exposed to the air into a silky thread or fibre. In this silky material the larva wraps itself up completely, and prepares for its change into a pupa or chrysalis. The mass of silk-fibre, with the chrysalis enclosed, is called a **cocoon.**

The pupa stage lasts from ten to fifteen days, during which time the larva changes into a moth. The moth then cuts its way out of the cocoon, and after living long enough to lay the eggs which are to develop into another generation of silk-worms, it dies.

Uses. The uses of the insect are obvious. From it is obtained the silk of commerce. The fibre is soft, pliable, lustrous, and immensely strong. It is woven into silk thread and silken fabrics, and forms a valuable export in many countries, notably in China, Japan, India, Turkey, Italy, and France. On the average it takes from 11 lbs. to 12 lbs. of cocoon to yield 1 lb. of reeled silk, and to obtain this weight about 2,800 cocoons are required. Each cocoon yields from 300 to 500 yards of silk, so that 1 lb. of silk fibre would reach from 500 to 1000 miles.

THE DRAGON-FLY.

The Dragon-fly belongs to the lace-winged order of insects known as the Orthoptera. Its larvæ inhabit the water, and for this reason, perhaps, are not so well known as those of butterflies and moths. The perfect insect includes a variety of forms, some brilliantly coloured.

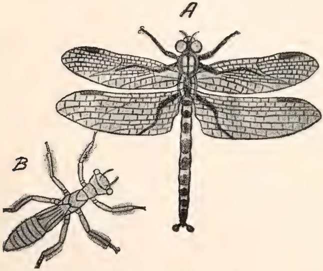


Fig. 87.—*A*, Large Dragon-fly. *(Uropetala carovei).*
B, Larva.
The figure represents a male form, distinguished from the female by two leaf-like appendages at the extremity of its body.

The large Dragon-fly—the one figured above—is not an uncommon insect in the months of January and February, when it may be seen dashing about, usually in swampy situations. It lives on flies and small insects which it pursues and easily captures, owing to the rapidity with which its powerful wings enable it to fly. It is a most voracious insect, and seeks its prey in full daylight, when the flies on which it feeds are darting to and fro in the sunshine. These, as soon as seized, are torn to pieces by its strong piercing jaws, and quickly devoured.

The larvæ of this and other Dragon-flies live in the pools over which the insects afterwards hover. They are, as a rule, dull coloured, and resemble the dusky vegetation on which they live. Like the fully developed insect, they are extremely voracious, and, although sluggish in movement, are able to capture the most agile insects, by means of a strong **labium** (or modification of the lower lip), which is furnished with powerful claws, and can be stretched out or folded away as occasion requires. There is no pupa, or resting stage, in the life-history of a Dragon-fly. The wings and other organs of the insect develop gradually, until at length the larva creeps out of the water, grasps some object, and rests until it is dry. It then casts its larval skin, and in a few hours changes into a swift aerial creature "innocent and gay to look at, but as hungry and cruel as the larva from which it comes."

Pupils will notice the three-fold division of the body; the six legs carried by the thorax, the long abdomen, the large and prominent eyes, and the huge jaws.

Uses. The larvæ prey on the larvæ of other insects—notably on those of the Mosquito—and as the Dragon-fly itself lives mainly on Mosquitoes and small flies, its use both in the larval and winged stages, in destroying insect pests, is at once apparent.

Another useful insect is the **Ladybird**, which both as adult and larva feeds upon Aphids and other destructive forms of insect life.

VII.—HARMFUL INSECTS.

The Codlin Moth. The Codlin Moth is one of the most formidable of orchard pests. It is not so very many years ago since it first found its way to this colony—since then its numbers have greatly increased until now there are but few places which are free from its ravages. The amount of injury it does to apples and pears is very great indeed—fruit worth many thousands of pounds being destroyed every year.

General Description. The moth is rarely seen, for it is small and dull in colour and does not fly about in the daytime. It measures across the wings about three-quarters of an inch and the length of its body is a little more than half an inch. In colour it is a greyish brown, the fore-wings having oval bronzed patches at their extremities, and the hinder pair being dark. During the day when resting it is seldom noticed, for its colour is almost identical with the bark of the tree to which it clings.

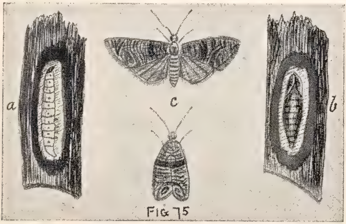


Fig. 88.—(*a*) The Caterpillar of the Codlin Moth resting behind the bark of an apple tree, and preparing for Pupa stage; (*b*) the Pupa stage; (*c*) the Codlin Moth flying and at rest.

It is first seen towards the end of October or beginning of November as soon as the apple and pear trees begin to blossom.

Life History. Each moth lays from fifty to one hundred eggs placing one at a time upon some particular spot. The place chosen is usually the crown of the apple shortly after the fruit is formed. The egg, however, which is white and about the size of a pin's head, may be laid on any part of the fruit, or even on the leaf.

At the end of about seven or eight days the egg develops into a small larva which immediately begins to bore into the apple, entering the fruit at the crown. It soon eats its way to the core, where it it lives for a fortnight or three weeks feeding on the pips and central part of the fruit; at the end of this time it emerges by eating its way out—an aperture larger than the one by which it entered being now necessary.

The larva should be examined and its colour, which changes from grey to flesh colour, noted. It is composed of segments, has three pairs of claw feet on the first three segments, four pairs of sucker feet in the middle of the body, and one pair on the last segment.

If the apple be on the ground when the larva emerges, it crawls to the nearest tree, finds its way up the trunk, enters a crevice in the bark, surrounds itself with a silken case and enters on the pupa stage. If, on the other hand, the apple has not fallen, the larva may lower itself to the ground by means of a silken thread, and then crawl to the trunk—or it may find its way back along the branches and down the stem. The larva does not always pass the pupa period in the bark of the apple tree — it frequently finds a resting place amongst dry twigs and leaves, in old fences, in crevices, in the floors of rooms where the fruit is stored, and in other suitable spots.

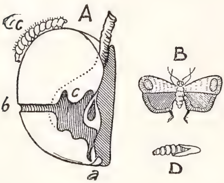


Fig. 89.

A, Apple, cut to show injury by Codlin Moth.
(*a*), Hole by which larva enters apple.
(*b*), Hole by which larva escapes from apple.
(*c*), Portion of inside destroyed by larva.
B, The Codlin Moth flying (enlarged).
C, Larva of Moth.
D, The pupa stage.

The pupa stage may last for a few weeks only, when another brood of moths issues forth to work further harm, or it may continue through the winter. Most of the larvae however remain in their cocoons until the following year.

The forms referred to in the following very brief account are amongst the most destructive and formidable of our insect pests.

Many kinds of **Beetle,** large numbers of which are to be found almost everywhere, do a great deal of harm both as larvae and fully developed insects. Their larvae are usually buried in the ground and are very destructive to the roots of grass or growing crops. In the final stage by means of their hard biting jaws they are able to devour the leaves and blossoms of plants.

Wire worms, which are really the larvae of the **Click-beetles,** devour the roots and stalks of plants, and, as they wander about from one plant to another, destroy far more than they eat. Unlike leaf-eating larvae they live for three years or more.

The **Turnip-flea,** or Turnip Flea-beetle, is a small active creature sometimes found in vast numbers on turnip crops if the conditions be favourable, *i.e.*, if the soil be dry. It may be recognised by its power of leaping into the air, often for a foot or more, also by the broad yellowish stripe which runs lengthwise upon each wing-cover. The Flea-beetle feeds on the leaves of both wild and cultivated cruciferous plants, being frequently found where turnips have never been grown though it thrives best where crops of this annual furnish it with food. Its eggs are laid on the under side of the leaves, and are deposited singly. The larva is a leaf-miner, burrowing into the soft tissue and leaving a discoloured track behind. It feeds for about seven days, then descends for a few inches into the ground, enters on the pupa stage, and at the end of about a fortnight emerges as a beetle.

The Crane-fly, commonly called Daddy-longlegs, produces larvae known as leather-jackets. The eggs are deposited just beneath the surface of the soil, and the larvae pass the winter under-ground. They are extremely destructive to many crops and to grass, devouring and destroying the roots of the plants.

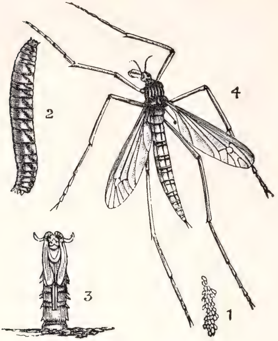


Fig. 90.—Crane Fly. (1) Eggs, (2) Grub, (3) Chrysalis, (4) Perfect Fly.

The Hessian Fly has long been a deadly enemy of the grower of Wheat and Barley.

The eggs, which are minute and red, are laid upon the leaves of these plants. The larva which issues from the egg feeds upon the leaf-sap, and, when full-fed, enters on the pupa stage within the plant itself. There it remains for a longer or shorter time and finally emerges a fly.

The Bot-fly of the horse in both the fully developed and larval stages is extremely troublesome to this animal.

The female hovering about the horse touches his skin with the tip of her abdomen. At that instant a sticky egg is passed out and firmly glued to one of the hairs near the tip. The sticky substance with which the egg is covered, on being exposed to the air, sets hard and cements the egg so firmly to the hair that it is almost impossible to remove it. The eggs, it will be noticed, are always laid in such a position as to be within reach of the horse's tongue, *e.g.*, on the flank, the shoulders, or the inside of the knees. The larva remains in the egg, and does not hatch out until the moment arrives for entering the horse. Warmed and moistened by the horse's tongue, it then escapes from the egg, enters the horse's mouth, and passes into the stomach. There, by means of a pair of strong hooks projecting from its mouth, it attaches itself to the mucous lining and feeds at the horse's expense until it is ready to pupate. When full-fed, it loosens its hold and passing down the intestine reaches the ground in which it enters on the pupa stage. There is no method

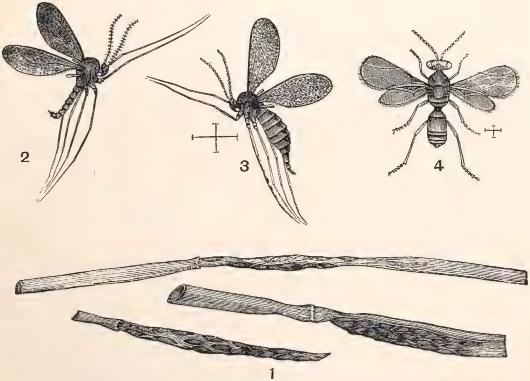


Fig. 91.—Hessian Fly. (1) Straw, with fly in chrysalis stage, showing damage to straw. This prevents the head from filling and causes the straw to fall. (2-3) Male and female flies. (4) Parasite, which lays eggs in chrysalis of Hessian fly, and so helps the farmer to fight the pest.

known of destroying Bots in the stomach. The only means likely to be effective in preventing the horse from being plagued is to keep his coat free from the eggs—this may

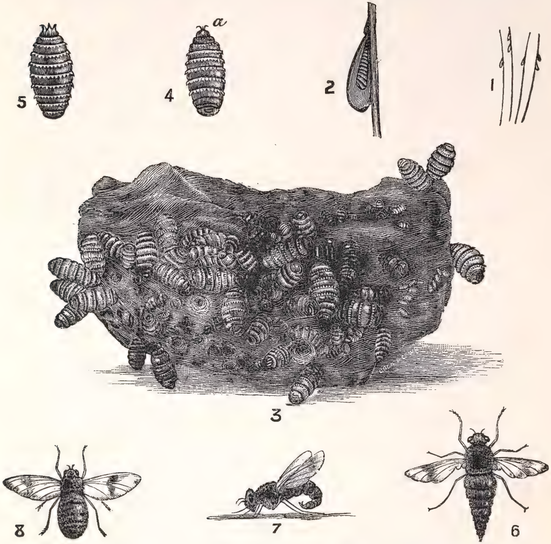


Fig. 92.—The Bot-fly. (1a) Eggs, natural size, from specimens obtained in Wellington. (2) The same, rendered transparent to show young, magnified. (3) Portion of stomach with larvae attached, also showing "pits" from which larvae have been removed, natural size. (4) Larvae further developed. (5) Chrysalis. (6) Female fly. (7) Side view of female, showing the way in which the abdomen is turned under. (8) Male fly.

be done by washing the coat where the eggs are fixed from time to time with hot water to hatch out any that are matured, or by removing the eggs as soon as they appear.

Aphids and Scale Insects. These are small insect-forms which are found in immense numbers on certain kinds of plants causing in some cases great devastation. The best known amongst the Aphids perhaps are the Blue Blight which often attacks cabbages; the Black Aphis so harmful to fruit trees; and the Phylloxera so injurious to vines.

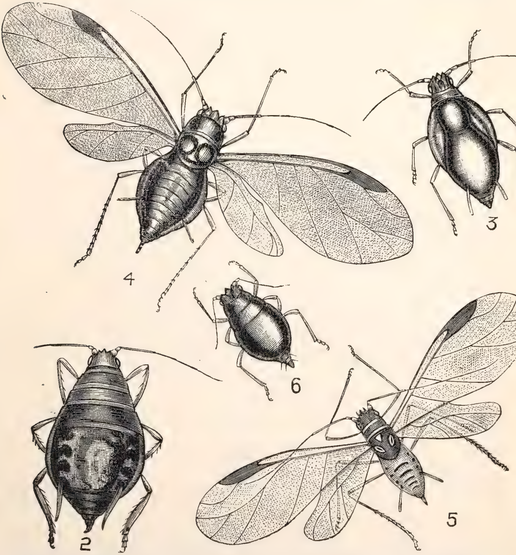


Fig. 93.—Black Aphis.—(2) Apterous viviparous female. (3) Pupa. (4) Winged viviparous female. (5) Winged male. (6) Oviparous female. All magnified.

Methods of Preventing Spread of the Insects. The insect itself is such a formidable pest that every possible means should be taken to lessen its ravages. The following are amongst the best methods of destroying it.

Before the larvae begin to appear, bands made from old bags should be tied round the trunks of the trees near the bottom as well as round the larger branches. The former will trap the larvae as they begin to crawl up the trunk and the latter wll catch those crawling back along the branches. These traps should be examined every week or ten days, and all the larvae destroyed.

The apples which fall off if they contain codlin-moth larvae should at once be collected and destroyed.

The ground underneath and around the trees should be kept free from rubbish of all kind *e.g.*, dead leaves and branches.

The bark of infected trees should be scraped and the scrapings collected and burnt.

The trees, when the apples are forming should be sprayed with a mixture of kerosene oil and soft soap. This to a large extent will prevent egg-laying—but as the eggs are not all laid at the same time, several sprayings are necessary.

A large number of injurious insects are to be found in all countries—our own islands supporting a formidable array of these destructive creatures.

Though it is highly desirable, indeed necessary, that those who are engaged in fighting these pests should have an intimate knowledge of their appearance and life-history, and though, moreover, many of the pupils in our schools may afterwards find such knowledge useful, yet it is beyond the scope of this book to enter into the subject with the necessary fulness of detail. For this the student is referred to *Miall's Injurious and Useful Insects* (Geo. Bell & Son, 3s. 6d.), and to Hudson's works on New Zealand Entomology.

Protective Colouring. A good lesson, or series of lessons indeed, can be given under this heading. Reference has already been made to several instances of protective colouring, and with a little trouble plenty of additional material can be collected, *e.g.*, the colour of different kinds of larvae—of Grasshoppers, Moths, Butterflies, Cicadas —Beetles, etc. compared with the general colour-effect of their surroundings. The similarity of the curious Stick-insects to the twigs of trees is familiar to most people, whilst the way in which the larvae of many insects surround their cocoons with pieces of bark to resemble the trees from which they are hanging, might be made use of as a further illustration of the need of protection when in the helpless pupa stage.

Rearing of Insects. For an account of the best ways of capturing the various kinds of insects and afterwards of arranging them for a school museum the reader is referred to Hudson's *Manual of New Zealand Entomology*, where the matter is fully dealt with. To this a few words may be added on the rearing of larvae. Subterranean larvae should be kept in moist soil; aquatic larvae must be reared in an aquarium; whilst carnivorous larvae must be supplied with flesh. Care should be taken to see that the food is fresh and the box well ventilated. Card-board boxes with glass covers and pierced with holes, or glass jars fitted with perforated lids are very convenient as cages. The bottoms of the vessels should be covered with moist sand or earth to hold the food plant of the larvae—an arrangement which serves to keep the food fresh and the air cool. It is sometimes necessary to place the plant-food in water; when this is done, care should be taken to cover up the vessel containing the water in such a way as to prevent the larvae from falling in and being drowned.

The following details should be carefully noted.

(*a*) Food-plant of larva.

(*b*) Number of days between each moulting.

(*c*) Changes which larva undergoes.

(*d*) Habits of larva *e.g.* whether a day or night feeder.

(*e*) Formation and description of cocoon.

(*f*) Number of days between first appearance of larva from egg and formation of cocoon.

(*g*) Duration of pupa stage.

NOTE.—The only real way for children to understand insect life is to follow the life history of a few forms through the various stages of development. Butterflies and Moths are the best subjects to work with ; and the eggs of the Silk Worm Moth, as also those of the commoner Butterflies are not difficult to obtain. These eggs should be placed in suitable boxes and the changes they undergo in the development of the perfect insect carefully noted. Pupils should be allowed to bring the food required and taught the necessity of regularly attending to the wants of the animals. A careful record in accordance with some such plan as that suggested at the end of the chapter should in all cases be kept.

There is no reason why a beginning should not be made in the Infant Department, where the initial stages might be devoted either to examining the structure of the insect, or to developing a few forms. If the former course be adopted, large diagrams are a necessity, as many of the insects most readily available, e.g Bee and Silkworm Moth, are so small that pupils have much difficulty in examining them. It is not to be supposed however that this advocates doing without the insects themselves ; these in some form must always be available, but no lesson can be considered complete in which diagrams and blackboard drawings are not utilized.

It has often be urged that a study of insect-life should be deferred until towards the close of the nature-study course. This contention has much to recommend it, for the creatures themselves are so small that there is difficulty in observing characteristic details, and, besides, there are many other forms of life in which little children are more interested. Still a good deal of useful work in the Infant Department can be done in the direction indicated ; though as in other phases of the subject much will depend on the tastes and knowledge-equipment of the teacher. In the upper classes special attention should be drawn to details, to the many ways in which insects are of service to us, and to the best means of checking the ravages of those harmful forms which do so much injury.

It is impossible in the scope of a work of the kind to do more than describe one or two forms and indicate how the subject may be further explained. When the forms suggested have been examined, others could be similarly dealt with ; and the points of difference and resemblance noted. Teachers who have a liking for the subject will find a plentiful supply of material ready at hand and might well make insect life contribute largely to the Nature-study course. *Miall's Injurious and Useful Insects*, published by Geo. Bell & Sons, contains much simply worded information, and would no doubt prove helpful.

Pupils should be encouraged to collect—noting when and where the forms are found and their habits. The specimens thus obtained could be mounted (named and classified if possible) and placed in the school museum.

It is unnecessary to add that the out-door study of insect-life offers a splendid field for investigation, for observation, for comparison and contrast. The useful purpose served by Bees and other forms can be learnt by seeing the insects at work ; the habits and habitat of both larval and winged forms can be noted—the advantages of protective colouring actually seen in operation—and many other features of interest learnt at first-hand.

VIII.—THE SPIDER.

A series of lessons on insects naturally leads to a description of an allied life-form, the Spider, which is popularly called an insect, but which we shall see differs in many respects from the creatures we have hitherto been examining. It belongs to a division of the **tracheata,** known as the **arachnida.**

General description. The body of the spider is made up of ringed segments ; but these fit so closely together that the joinings cannot be seen. It consists moreover of two distinct parts, the head and thorax being fused together. The **head-thorax** bears **eight** legs, each of which consists of seven joints and ends in a claw. The large number of joints enable the legs to be easily moved about, an arrangement which greatly assists the animal in spinning its web. The eyes of the spider are not compound, but single — the number and plan of arrangement of these vary considerably—most spiders have either six or eight eyes.

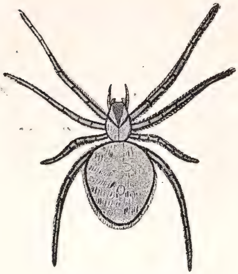


Fig. 94.—The Spider.

In front of the head are the two feelers, which are really a pair of strong mandibles each ending in a powerful claw. These claws consist of two joints, the lower one being large and thick and having a furrow along its inner margin. Into this groove the outer claw-like joint can be folded when not in use—just as the blade of a pocket-knife is shut back into the hollow space in the handle. The feeler is in reality a hollow tube leading to a poison gland. When the spider seizes its victim, it can force a drop of poison through the claw into the wound with fatal results to the captured insect.

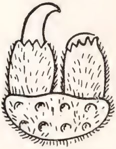


Fig. 95.—Mandibles, showing one claw extended and the other folded back into groove.

Respiration. On the under-side of the abdomen near its junction with the head-thorax are two slits which open into small flattened air-chambers, the walls of which are folded into a number of delicate leaf-like plates. These are the breathing organs of the spider. The blood circulates through these delicate folds, and is thus brought into contact with the air, which is drawn in and forced out by a special set of muscles. In addition to the air-chamber spiders possess tracheæ through which respiration is carried on.

Making the thread. At the end of the abdomen on the under side are little round swellings. These are the **spinnerets** with which the spider makes its silken thread. Each spinneret consists of hundreds of fine tubes through which the animal is able to squeeze the liquid made by the spinning glands. The ends of the hind feet terminate in claws, which are split up along the margin into a number of teeth. These claws are known as combs and by their means the spider is able to twist into a single line the thousand of delicate threads which come from the spinnerets. The advantage of this is obvious. The liquid made by the spinning glands hardens on being exposed to the atmosphere, but the hardening process is greatly hastened by separating the fluid in this way and so exposing a greater surface to the air. The strength of the finished thread moreover is largely increased by twisting a number of strands together; just as a wire rope is much stronger than an iron rod of the same thickness.

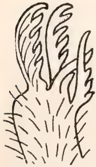


Fig. 96.—Hind foot.

Making the web. In making the web the spider stretches a strong thread between two supports. This it does either by fastening one end, dropping down to the ground, and walking across to the opposite support; or by letting a long thread float loosely in the air until the wind carries it to some suitable support, to which, being viscid, it firmly adheres. When the first line is secured, other foundation threads are thrown out in such a way as to radiate from a point like the spokes of a wheel. These are then seized by the claws and pulled taut. The next process is to lay the cross threads which are finer than the "ray" threads or framework of the web. In placing these the Spider starts from the centre and goes round and round stretching a series of short threads between the rays, and following a spiral round the centre. The spiral threads are covered with little beads of gum, which serve to hold any insect coming in contact with them. The centre of the web is free from this viscid substance, for it is there that the Spider lies in wait for its prey. The spiral threads are renewed each day so that the snare is always in readiness for the capture of victims.

The web is built mainly, if not entirely, for the capture of insects. The Spider waits for his prey either in the middle of the web, or in some convenient hiding place close by. If he leaves the web, he draws after him a " signal-line," by means of which he instantly knows what is going on, for the shaking of the web by causing the signal-line to vibrate at once reaches him. If the insect be a small one, the sticky substance on the web is sufficient to hold it, and it may be left where it is until the spider is ready to devour it. If, on the other hand, the victim be large and powerful, it is surrounded with silken threads and then killed by means of the poison fangs. As soon as it is killed, the Spider either sucks the juices out of its body —or, rejecting such hard dry portions as the wings, cuts up the body into small pieces which are drawn into its mouth.

The Spider lays eggs from which the young are produced. Unlike the egg of the insect, which develops into a larvae, the Spider's egg hatches directly into a young Spider. The eggs are usually laid in a bag, made of strong silken fibre, which in some cases is carried about. The young Spiders grow with rapidity and in doing so are constantly obliged to cast their skin. After each fresh change of skin they are very helpless; and frequently fall a prey to their many enemies. Each change, moreover, is accompanied by an increase in size ; after the last change they are full grown.

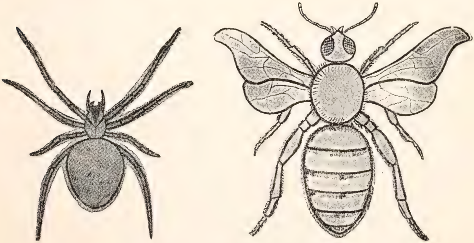


Fig. 97.—Spider and Insect.

A COMPARISON AND A CONTRAST.

A comparison and contrast between the two groups of animals, Insects and Spiders, will bring out the following details. Both are furnished with jointed limbs, some of which end in claws. In both the body is soft and covered with a tough skin. In both the oxygen required for respiration is derived from the air, and both are able to spin silken threads.

They differ (a) in the divisions of the body, the body of the Insect consisting of head, thorax, and abdomen, and that of the Spider of two segments only (the head and thorax being fused together) the head-thorax and abdomen ; (b) in the number of legs, the Insect having six and the Spider eight ; (c) in the kind of appendages borne, the

Spider in no case being furnished with wings; (d) in the manner of respiration—the Insect breathing through spiracles communicating with tracheae, whilst the Spider in addition to tracheae has two large breathing chambers or lungs; (e) in the organs of sight—the Insect having both simple and compound eyes, and the Spider only simple eyes; (f) in their life-history—the Insect passing through the egg, larval and chrysalis stages and growing no more after having emerged from the chrysalis; and the Spider resembling its parents in all respects directly it is hatched from the egg; (g) in their manner of spinning the silken thread—the Insect-larva, which spins a silken cocoon, passes the thread out from its mouth, and never weaves a web to catch insects, whilst the Spider is provided with spinnerets and combs for twisting the threads together; and weaves a snare for the capture of prey.

NOTE.—The work suggested in this chapter might with advantage be deferred until some of that dealing with Insects be worked through. Pupils will then be in a position to appreciate the difference between the two forms.

As in the case of Insects, large well-drawn diagrams or blackboard drawings are essential. These should be sufficiently large to be seen by the entire class, and should avoid all unnecessary detail. It is this suppression of detail which often raises the home-drawn diagram above the level of usefulness reached by the published chart. Details which are not required at the time are for the moment suppressed, with the result that attention is concentrated on a few special characteristics, which are thus understood and impressed with thoroughness.

The structure of the web could in many cases be observed out of doors—indeed this should be done wherever possible—and experiments should be made with the object of testing the strength of the silken fibre of which it is composed. Under favourable conditions the actual work of web-building might be observed.

Lessons on the Garden Spider might be followed by those on other kinds of Spiders, *e.g. Water Spiders*; or, in the case of the more advanced pupils, might be supplemented by information about various kinds of Spiders. If this be done, the work should be well illustrated by diagrams, drawings, and pictures.

IX.—VERTEBRATE ANIMALS.

INTRODUCTION.—The Vertebrates, or backboned animals, we have seen, are divided into five classes, viz.—

Fish ;	Birds ;
Amphibians ;	Mammals.
Reptiles ;	

We shall now proceed to examine these in detail selecting typical examples of each class, with the view of discovering their distinguishing characteristics, and of learning something of their habits.

THE FISH.

Shape. The typical fish, such as Mullet or Kahawai, is shaped like a boat, tapering both to the head and tail. The wedge-shaped head enables the fish to cut through the water with ease and the tapering tail prevents, to a very large extent, a retarding " swirl " from taking place in the liquid as the animal moves along. There is no neck, the head being united directly with the body, which unlike that of most other vertebrates, is not distinctly marked off from but passes gradually into the tail. The broadest, thickest and hence heaviest part of the fish is the shoulder, which is usually situated back from the head and nearer the head than the tail : it is in fact from this thickened region that the fish tapers both fore and aft, and its position tends to keep the head in the proper direction during rapid movement through the water.

TYPICAL FISH.

Scales. The body of the fish is covered with hard slimy cartilaginous overlapping scales, each scale having a fixed end towards the head and a free end towards the tail. This arrangement causes the scales to lie close to the body whilst the animal is swimming and hence increases the ease of locomotion. The slimy covering serves the twofold object of lessening the friction as the animal moves along, and of allowing the scales to move over each other with greater ease. Pupils will see how extremely well adapted are these scales to the purpose they serve. The fish is a cold-blooded animal, as we shall learn further on, and hence does not require a warm covering *e.g.* of wool or feathers: such a covering would not only be unnecessary but would greatly retard the movements of the animal. The scales furnish just the covering required, being light, flexible, and hard, and provide the fish with a closely fitting armour which protects it from injury. Running along the side of the body is a series of perforated scales known as the **lateral line.** It is from this region that the slime is poured out—the pores being connected with the long chamber or canal which secretes the mucus or slimy material The lateral line moreover acts as a sense-organ, being the seat of a large number of nerve-endings, which enables the fish to feel the slightest vibration and to realise the approach of danger.

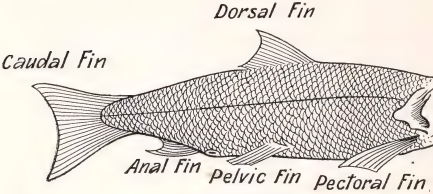


Fig. 98.—Typical Fish.

Fins and Tail. The fins fall naturally into two groups viz: the paired and unpaired fins. The paired fins are the **pectoral** fins, situated on the breast immediately behind the opening leading to the gills, and the **pelvic** fins also situated near the under surface of the body and usually further back than the pectoral. The paired fins correspond to the limbs of other vertebrate animals, though differing considerably from these in structure.

The unpaired fins are the **dorsal** or back fins, the **anal** fin placed on the under surface of the body and behind the pelvic fins, and the **tail** fin. These (dorsal, anal, and tail) are sometimes spoken of as the median fins, because they occur in the plane which divides the fish into two equal and similar portions.

A fin is an expansion of the skin supported on a number of cartilaginous or bony rays, connected by muscles by means of which they can be expanded, folded up, or moved about. In many cases the fin-rays project beyond the fin-membrane and end in sharp stiff points, which furnish a formidable means of defence. The tail fin is an expansion of the skin covering the true tail, which consists of solid bone or of cartilage. In most fishes the fin-membrane is expanded into two equal and similar lobes—in the Shark and a few others the lobes are unequal.

The eyes are well in front of the head and in most forms near the upper surface. These organs are large, circular, and covered with a horny transparent substance which protects them from injury. There are no eyelids, the water which continually washes the eyes rendering eyelids unnecessary.

The head is covered with a number of hard bony plates, one of which the **operculum,** or gill-cover, closes the opening leading to the gill-arches. There are of course two opercula, one on each side of the head.

The gills and their uses. Fish, in common with all other animals, breathe air; but the air they require is dissolved in the water in which they live. If a glass vessel be filled with water and placed over the flame of a bunsen burner or a spirit lamp, bubbles of air will be seen to rise through the liquid. The air has been dissolved in the water and is driven off when the liquid is heated. It is for this reason that the water in which Gold-fish are kept requires to be constantly renewed —and why, moreover, a more frequent change of water is necessary in a small vessel than in a large one. The fish has special breathing organs, called **gills,** to enable it to breathe under water. If the gill-cover be raised or removed, the gills will be exposed; these consist of feathery fringes of red flesh growing from the gill arches. The fringes themselves are crowded with blood vessels covered with a moist skin so thin that we can see the red colour of the blood within. If a fish be watched, it will be seen to be constantly opening and closing its mouth, as if it were drinking. The water however is not swallowed but is passed backwards over the gills and out again through the gill-openings at the sides of its head. In its passage over the gills the dissolved air diffuses through the thin moist walls and enters the blood vessels, whilst the carbon-dioxide carried by the blood diffuses into the water. The gills in fact are to fish what lungs are to the other vertebrate animals. Fish living in rivers or in currents, point their heads up stream, as in this position a flow of water over the gills is more easily obtained. Anglers are able to drown fish by leading them down stream and so preventing a sufficient supply of water from entering the gills. If a fish be removed from the water it quickly dies, not in consequence of an insufficient supply of air but because the gills become dry, which retards the circulation of the blood, and hence prevents the diffusion of oxygen into the blood vessels. Some fish—notably Eels—are able to live for a long time out of water because of an arrangement which keeps the gills moist. In the case of the Eel, the gill-opening is small and far back—so that a cavity is formed by the water in which the gills are constantly moistened.

The body of the fish always feels cold.—This is not because it lives in the water, for other animals which live in water are not cold-blooded e.g. the Whale and the Seal. Fish are sluggish breathers and take in so little air that it is not sufficient to warm the blood in their bodies. The circulation of the blood moreover is very slow—the heart being a relatively weak organ. In the case of a warm-blooded animal such as a Rabbit, the heart not only drives the blood to the lungs, but forces it over the body through special blood-vessels—the heart of the fish merely sends the blood to the gills, from which it finds its way slowly through the blood-vessels of the body and back again to the heart.

Locomotion. The fish swims by means of its tail and fins; but the former is by far the most important organ of locomotion. The tail, which is controlled by strong muscles is moved rapidly from side to side; this brings about a backward and forward movement as well—a process which forces the animal through the water just as a man propels a boat by the action of a single scull passed over the stern. The tail-fin also acts as a rudder enabling the fish to alter its course with rapidity.

The fish tapers from the back to the under surface, hence the heaviest portion is that along the back, so that by the laws of gravitation this part ought not to be uppermost. Its position is maintained by the paired fins which act as balancers, as may be shown by fastening the pectoral and pelvic fins of a living fish to the sides of its body—if this be done the animal will turn over on its back. Again a dead fish floats on its back, for the fins cannot balance it as they did when alive, and the heaviest part naturally takes the lowest place in the water. The paired fins moreover help to control the movements of the fish in other ways. The pectoral fins for instance can be employed as a brake, or used in such a way as to drive the fish backwards. Again, if held forwards and downwards whilst swimming, the pressure of the water on their upper surfaces causes the animal to descend; whilst by extending them backwards and downwards the pressure on the under surfaces causes the fish to ascend. The unpaired fins act in the same way as the keel of a boat, serving the purpose of a cut-water, and helping to steady the fish as it moves along. The extreme freedom of movement possessed by the paired fins, as also the great flexibility of their joints, should be specially noted.

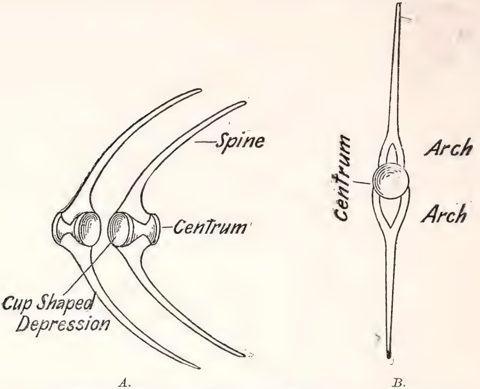


Fig. 99.—Vertebrae from tail region.—*A*, showing double row of spines and cup-shaped depression in centre. *B*, arches in spines.

The back-bone and teeth. Amongst the most characteristic bones of Vertebrates are the backbone and the teeth. In the fish each vertebra consists of a rounded **centrum**, (solid central part) on either side of which is a cup-shaped depression. The centrum of one vertebra is joined to that of the next along the rims of these cups, so that a hollow space is left between the two. This is filled with an oily fluid, which helps the edges to move freely upon each other. From the upper and lower surfaces of the centra in the caudal vertebrae two spines project for some distance—i.e. one from each surface, the length of these varying considerably. Each spine curves backwards, and forms at its base a conspicuous arch.

The mouth of the fish is well provided with teeth, which are usually small, numerous, and sharp, and are set in the jaws in such a way as to point backwards towards the throat. There are no grinding or tearing teeth. The structure and position of the teeth often throw a good deal of light on the habits of the animal to which they belong. For example, the absence in the fish of grinding and tearing teeth teaches us that the prey is swallowed whole. The backward slope and sharp points of the teeth enable the fish to seize and hold the struggling slippery animals on which they feed. Some fish have teeth specially shaped for crushing the shells of molluscs—the Schnapper is able to use its powerful jaws and teeth for this purpose.

The Flounder.

General Description. The body of the Flounder is boat-shaped, with the broadest part slightly nearer the head than the tail. The purpose served by this arrangement has already been explained. The upper side is dark and convex, whilst the under side is almost white and relatively flat, the whole being covered with closely fitting scales, which are easily removed. On both sides the **lateral line** is well marked, the red colour on the under side rendering it very conspicuous. The head is small and flat and carries on its upper surface a pair of eyes placed

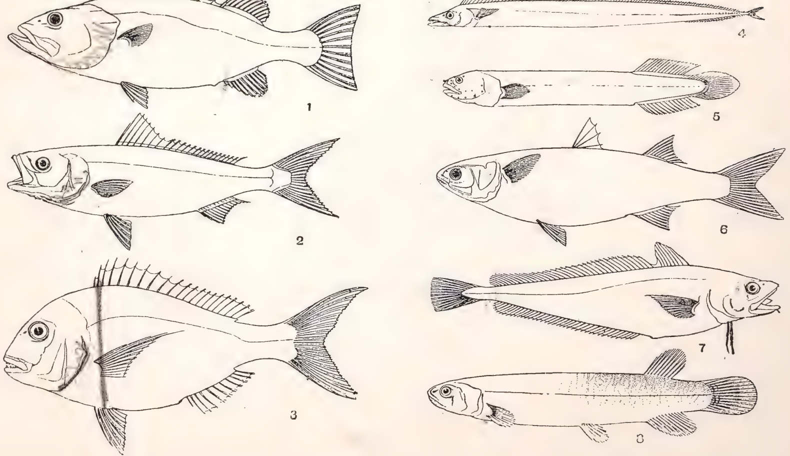


Fig. 100.—1. Hapuka. 2. Kahawai. 3. Schnapper. 4. Frost-fish. 5. Mud-fish. 6. Mullet. 7. Red Cod. 8. Kokopu.

side by side and close together. The mouth is small, having both jaws furnished with fine pointed teeth. There are two **pectoral** fins immediately behind the gill slits. The **dorsal** and **anal** fins are prolonged into a fringe running completely round the body.

Development of Fish. The upper and under surfaces correspond to the two sides of the body, as shown by the presence of the lateral line and the horizontal position of the tail: that is, the animal spends its life with one side of its body uppermost. When newly-hatched, the young fish are spindle-shaped and swim about near the surface, back uppermost, but, as they grow older, they become broader and thinner, assuming a shape which renders it difficult to maintain an upright position. They are for this reason gradually compelled to lie on one side, and ultimately lose the power altogether of maintaining the normal position.

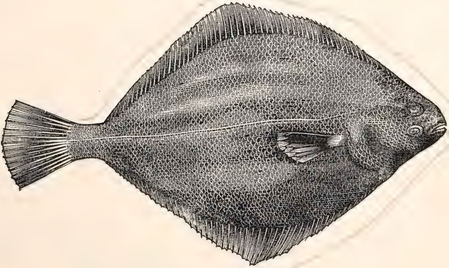


Fig. 101.—The Flounder.

Movement of Eye. When the fish is young, the eyes are one on either side of the head. As the animal grows older, however, and swims on its side along the bottom, the eye would not only be useless on the under surface, but would run almost certain risk of being injured. It therefore begins to change its position and gradually works round to its final place beside the stationary eye. In some flat-fish the eye reaches the upper surface by sinking *through* the head.

Colour. The movement of the eye is not the only change undergone by the animal. When young the colour on both sides is the same; it is only when it loses the power of being able to maintain its upright position that the under surface becomes white. This change of colour in the adult fish appears to be due to the effects of light acting on the eye and thence on the nerves connected with the pigment cells in the skin.

The dark colour of the upper surface is a great protection against enemies, rendering the animal almost invisible when lying on the soft sand and mud of the sea-bed. Those who have waded over sand-banks spearing Flat-fish will know how extremely difficult it is at times to detect the animals, the colour of the upper surface being almost identical with that of its surroundings; and when, as frequently happens, it buries itself in the mud or splashes sand over its body, it is quite impossible to see it.

Method of swimming. Most fish propel themselves through the water by a side to side or horizontal movement of the tail. This the Flounder is unable to do, for its tail is carried in a horizontal position. In swimming it moves through the water by throwing its body into a number of curves, so that the dorsal and anal fins which in most fish act as cut-waters, are used by the flounder as a means of locomotion.

NOTE.—Here again it is not intended that classification should precede individual study; as representatives of each division are dealt with, their characteristics can be emphasised and pupils gradually led to recognise the similarity shown by all animals belonging to the sub-kingdom, as well as the differences which determine the classes. In other words the classification should be incidentally learnt during the progress of the lessons.

Differences of opinion may exist as to the best time for introducing some of the forms belonging to the sub-kingdoms described in the earlier portion of Part II. With the Vertebrate animals, however, the case is different; all of these likely to be examined will furnish suitable material for investigation in any department of the school. Most of the animals are well known and can be invested with interest both for young children, as well as for those in the higher classes.

In dealing with the fish, some familiar form should be selected, *e.g.* the Schnapper, Kahawai, or Mullet. The description given in the preceding pages will apply to any of the kinds most easily procured. The study of this class of Vertebrates should extend over several lessons, and during its progress a number of individuals should be examined. It will be necessary to procure both dead and living specimens, the latter can be shown in large glass vessels, when the manner of swimming, the use of the fins and the method of passing water over the gills, may be learnt by observation.

When dealing with the bony framework, it may be difficult to obtain a complete skeleton, but this, although highly desirable if it can be procured, is hardly necessary for the purpose in view. A few typical vertebræ, with the head carrying teeth and surrounded with bony plates, will be quite sufficient for the purposes of illustration. This part of the subject, however, should not be dealt with in the initial stages of the course.

X.—THE FROG.

The frog belongs to a class of vertebrate animals known as **amphibians,** which differ from fishes mainly in the structure of the limbs, in the absence of fins bearing fin-rays, and in the manner of respiration.

General Description. The common Grass-frog is a short, broad, thick-set animal with a large, wide, triangular-shaped head, which, like that of the fish, is set on its shoulders without any neck. Its mouth is extremely wide, and its large, prominent eyes are surrounded with yellow edges. Its body is furnished with four limbs, the hind-limbs being much larger and stronger than the fore-limbs. In its favourite position resting on its haunches, it presents an ungainly and awkward appearance. Its skin is smooth and moist, and feels cold to the touch.

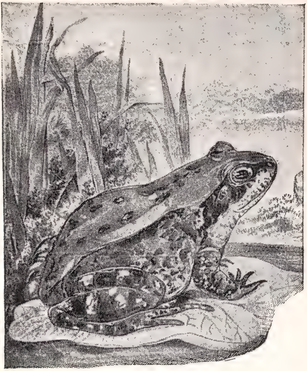


Fig. 102.—The Frog.

The Limbs.—The front limbs differ from the hind limbs not only in being shorter, but in having four toes, which are not webbed. The hind limbs end in five toes, between which a flexible membrane or web is stretched. The structure of the limbs in itself would indicate that the animal is not adapted for walking. It moves on land by leaping or jumping, for which its strong hind limbs are admirably suited. In the water it swims with considerable rapidity by kicking out vigorously with its hind limbs, the broad, webbed feet offering the necessary resistance to the water.

The Mouth.—The mouth is wide and deep; indeed the whole head of the animal seems to open when the jaws are gaping. The upper jaw contains a row of fine teeth along the margin, which, like those of the fish, point backwards towards the throat. In the lower jaw there are no teeth.

The Tongue. The forked tongue is attached to the front and middle part of the lower jaw, and, when the mouth is closed, points backwards in the same direction as the teeth. This arrangement enables the tongue to be thrown forward and flicked out to its full length. It is covered, moreover, with a thick slimy matter, which sticks tenaciously to its prey.

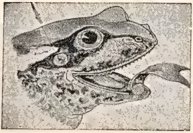


Fig.103.—Head of Frog, showing attachment of Tongue, and its action in catching Flies; also Ear-drum (*a*).

The Skin.—The skin is very porous, and is kept moist by a slimy fluid, which is constantly poured out from numerous small glands. The evaporation of the moisture serves to keep the body cool even when the weather is hot, a matter of the utmost importance to an animal which cannot live when the temperature rises beyond 100° F.

Respiration.—Respiration takes place through the lungs and skin. If a resting Frog be watched, it will be seen to lower and raise the floor of the mouth alternately—this action being part of the process of breathing, which is carried on as follows: The mouth is closed, the floor of the mouth depressed, and the nostrils are opened. This causes air to be forced in through the nostrils. These are then shut, the floor of the mouth is raised, and the compressed air flows into the lungs. Here an exchange takes place between the carbon-dioxide in the blood in the capillaries lining the walls of the lungs, and the oxygen contained in the inspired air. When the air has thus been driven in and out of the lungs a few times, the nostrils are opened, and the impure air is expelled. A constant repetition of this process enables the animal to obtain the greater part of the oxygen required. The Frog's breathing, however, is not confined to the lungs, a considerable part of it being carried on through the skin. The skin is thin and moist, with numerous blood-vessels in its inner surface. All the essentials of a breathing organ are, in fact, present —viz., plenty of free oxygen separated from blood-vessels by a thin, moist membrane, so that a supply of oxygen can be and is obtained through the skin. It is for this reason that the Frog is able to live so long under water; indeed, it is practically impossible to drown a frog in ordinary water, where the dissolved air supplies the animal with the oxygen needed.

The foregoing will show how necessary it is that the skin be kept moist, and explain why the Frog, when in the sun, does not remain long out of water, and why, moreover, it invariably selects as its abode a cool shady spot.

A Cold-blooded Animal.—The Frog is a cold-blooded animal like the fish, and for very much the same reasons; the supply of oxygen it requires and hence absorbs is not sufficient to raise the temperature of its body, which always feels cold to the touch. It is because the animal has but little bodily heat to keep in, that it is not provided with a warm covering, or, inversely, because it is not provided with a warm covering it can have but little bodily heat to keep in. A naked animal, if warm-blooded, would not be able to live in the water for months together, as the Frog does, unless, like the whale, it were specially protected against cold.

The Frog's Food.—The Frog lives largely on insects, which it catches by means of its tongue. The prey, however, is not attacked unless it is moving; an insect at rest is watched intently until it begins to move, when the tongue is rapidly darted forward and carried back to the mouth again with the insect on the tip, the sticky secretion with which the tongue is covered helping to secure the almost certain capture of the prey. In addition to insects, the Frog devours slugs, grubs, worms, and snails, and is, in fact, one of the gardener's most useful friends.

Habits of the Frog.—Frogs are to be seen in large numbers from spring to autumn in ditches, reedy pools, and marshy ground generally. As winter approaches they bury themselves in the mud at the bottom of sheets of water, and remain there in a state of torpor until the approach of spring. During their winter sleep, the mouth and nostrils are closed, and respiration is carried on entirely through the skin. As we have seen, the animal is equally at home on land or in the water; on land, it progresses by long leaps, and in the water it is able to swim with ease and rapidity.

The Laying of Eggs.—Soon after emerging from their long sleep, the animals begin to pair and the females lay their eggs or spawn. It is at this time that so much croaking is heard. Both males and females croak, but the male is able to make more noise by means of a pair of vocal sacs with which he is furnished. These lie immediately behind the eyes, and can be inflated with air from the mouth.

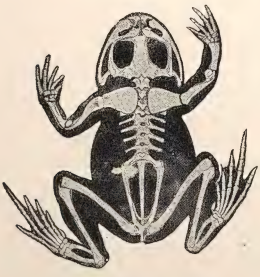


Fig. 104.—Skeleton of Frog.

So soon as the eggs are laid they are abandoned, and the animals leave the water and resume their ordinary life on land, until the change of seasons again compels them to go into winter quarters.

Bony Framework.—Figure 104, which shows the skeleton of the Frog, will indicate the build of the animal. Note the low depressed skull, the large orbits, the difference in the length of the fore and hind limbs, the number of digits on each limb, and the absence of ribs enclosing the chest.

The Egg.—A Frog's egg, when first laid, is a small spherical body covered with a thin gelatinous layer, which quickly swells up in the water into a transparent globe, in the centre of which a small black speck, the true egg, can be seen. The jelly surrounding the egg serves a two-fold purpose. It acts as a float, keeping the eggs at the surface of the water, and enabling them to obtain the warmth necessary for their development. It is, moreover, extremely slippery and difficult to grasp, and so serves as a protective covering against the attacks of birds, fishes, and the larvæ of insects.

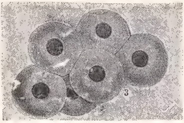


Fig. 105.—Eggs, showing small black speck enclosed in globe of jelly

The Tadpole.—In a short time the spherical mass developes into a small black elongated creature, all head and tail, known as a Tadpole. On first emerging from the egg, the tadpole is very helpless; it has no mouth, and makes but a poor attempt at swimming. When in this condition, it attaches itself to water weeds, hanging on by means of suckers, with which the underside of its head is provided. On the sides of its neck are several pairs of fine hair-like outgrowths—the *external gills*, by means of which it is able to breathe. In a few days its mouth appears, the animal then begins to bite at the vegetation, and swims about by means of its long flexible tail. The external gills gradually disappear, and a series of slits opens on the sides of the head—these are the *external gills*. The animal is now to all appearances a fish, obtaining a supply of oxygen through its gills, and being unable to live out of water.

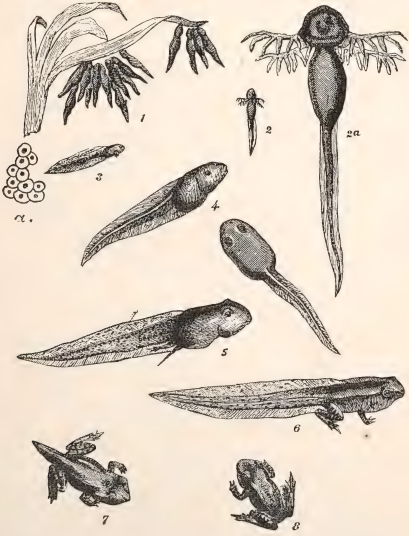


Fig. 106.—Life stages of Frog—newly-hatched Tadpoles to the young: (*a*) eggs, (1) Tadpoles just hatched, (2) Tadpole with external gills, (2*a*) fig. 2 magnified, (3) side view of fig. 2, (4) Tadpole with internal gills, (5) Tadpole showing hind legs only, (6) Tadpole during the metamorphosis, (7) young Frog with tail only partially absorbed, (8) Adult.

Its mouth is on the front under surface of its head, a position which enables it to nibble at the soft parts of the water plants, upon which it feeds. The tadpole grows with considerable rapidity, and, at the end of some weeks, (from four to eight) two small swellings begin to make their appearance one on either side of the body near its junction with the tail. The length of time which elapses before this change occurs will depend on the weather, warm, genial weather favouring a rapid development. The swellings referred to gradually increase in size, and finally take the form of limbs, which greatly assist the Tadpole in swimming. As the hind limbs are forming, two other swellings make their appearance, one on either side of the body near the head. These, too, grow rapidly, and at last forcing their way through the skin appear as a pair of fore-limbs. In the meantime, the tail has been getting smaller, and usually by the time the four limbs are fully formed has disappeared altogether.

The whole appearance of the creature has now changed; its head and body have grown large and broad; its eyes stand out prominently, and its mouth is quite in front of its head. Changes, too, are taking place in its internal organs, fitting the animal for its life on land; the gills gradually close up, and lungs begin to form inside.

NOTE.—The tail is not cast off, but gradually absorbed during the period of transformation.

The Tadpole has now been transformed into a Frog; it no longer cares for the vegetation of the water-pools, for it has become a flesh-eater. Small at first, it grows rapidly, shedding its skin from time to time, as this becomes too small for its increasing size. The older skins, as they are cast, are devoured by the animal itself.

The New Zealand Frog.—The Frogs which are so numerous in these islands are not natives of this colony, but have been introduced from other countries.

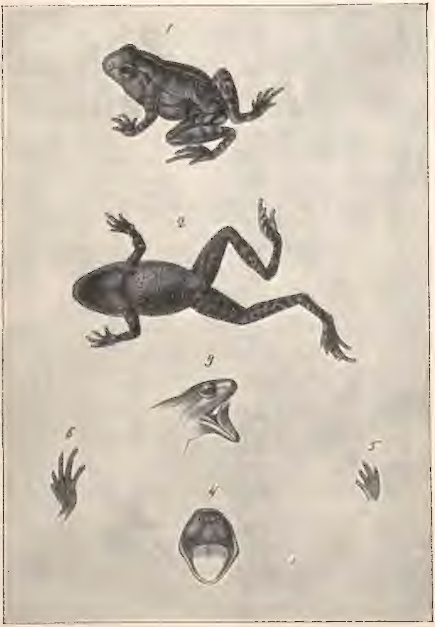


Fig. 107.—New Zealand Frog.

1 Side view. 2. Lower surface. 3. Side view of open mouth. 4. Open mouth. 5. Fore-foot. 6. Hind-foot.

There is one species of Frog, however (*Liopelma Hochstetteri*), which is found in New Zealand, and nowhere else; but it is very rarely seen, and nothing is known of its habits. It occurs chiefly in hilly country in the neighbourhood of streams, and no doubt the young Tadpoles live in the rock-pools along the water-courses.

In addition to Frogs, amphibians include Toads, Newts, and Salamanders. Frogs are the only amphibians found in New Zealand.

NOTE.—The lessons on this subject should be deferred until spring or early summer, that is, until frogs are plentiful.

The examination of the animal itself should precede an investigation of its life-history, and should be a real examination and not a mere description of illustrative pictures, though these will be found helpful in clearing up difficulties and emphasising what has been learnt.

The bony framework, or as much of it as we are concerned with can be felt through the skin; the skull, backbone, bones of the limbs, and breast-bone can all be made out, as also the manner of attachment of the limb-bones, and the absence of ribs.

The development of the Frog should be worked out in the school aquarium. A simple form of aquarium is made by covering the bottom of a fairly large vessel with mud, fine gravel, and a few small stones smeared with green slime. These should be arranged in such a way as to shelve from the surface at one side to a depth of five or six inches at the other, and have the slime-covered stones resting on the bottom. A few water weeds should then be planted, and all suspended sediment allowed to settle down. The next thing is to procure some Frog spawn. This might be done by the pupils under the guidance of the teacher, when the protection offered by the gelatinous covering could be tested. If the weather be warm, the eggs will develop into tadpoles in a fortnight or less. It will be necessary to supply green slime from time to time for the animals to feed on.

The number of Tadpoles reared should not be great, as their growth and development can be more readily watched when there are only a few.

Careful records of everything done and observed should be kept, with special reference to dates, *e.g.*, date when eggs were obtained, when first Tadpoles appeared, when indications of limbs were first seen, etc., etc.

XI.—REPTILES.

INTRODUCTION. — **Lizards.** Lizards belong to a class of vertebrates known as reptiles, in which are included Snakes, Crocodiles and other similar forms. They may be described as cold-blooded air-breathing vertebrates in which gills are not developed at any period of life.

The reptiles which occur in New Zealand are, with one exception, entirely confined to a single order — viz. **The Lizards.** These are found in considerable numbers in both islands and some of the forms are easily obtained. They live for the most part on insects, and if care be taken to supply them with these, as also with water to drink, they can be kept in confinement sufficiently long to allow their habits to be observed.

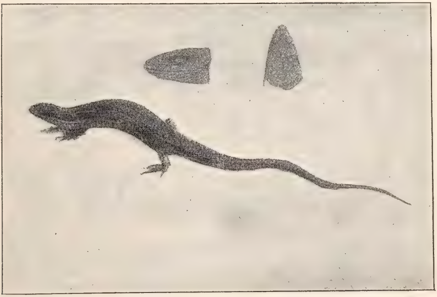


Fig. 108.—Common Lizard.

The Common Lizard (*Mokomoko*). This form is found both in the bush and in the open country, under stones, logs, leaves, or anything that will afford sufficient cover. The colour of the animal varies considerably with the individual. As a rule the back is reddish brown, either pale or dark, with a whitish stripe extending from the nostrils over the eye and down the side. A dark stripe frequently runs along the centre of the back, and the under surface of the body is yellowish or greenish.

The head is broad and depressed, and the mouth which is large, wide, and furnished with teeth, is on the under surface. The eyes are large and prominent, and placed near the upper surface of the head.

The body is long and narrow, and ends in a tapering tail about one and a half times the length of the body, the whole being covered with scales. A well-grown form reaches about seven inches in length.

There are four limbs each ending in five toes. By means of these the animal can progress with fair rapidity, a curious undulating movement of the tail accompanying its progress.

In common with other reptiles the lizard is cold-blooded. Breathing is carried on by means of lungs, but the amount of oxygen required by the animal is not sufficient to make the blood warm.

The Tuatara (*Sphenodon punctatus*). One of the most remarkable reptiles found in New Zealand is the Tuatara, an animal belonging to an order differing from that which includes the Lizards. The reptiles of this order in past ages had a wide distribution, and were amongst the earliest forms of reptilian life. They have long since disappeared in other countries, and at present are found only in New Zealand. Not many years ago they occurred in many parts of the Auckland Province, but they are now confined to a few of the outlying islands near the coast.

In colour the animal is yellowish or greenish olive with yellow spots.

The head is large and bird-like. The body is covered with scales, those on the under surface being larger and better developed than the ones on the upper surface. A low crest of horny spines runs along the back, neck, and tail. The male forms have larger crests than the female. The limbs are thick and strong and end in five toes.

Opportunities for examining the Tuatara must necessarily be limited, the description of the animal has, therefore, been made as brief as possible.

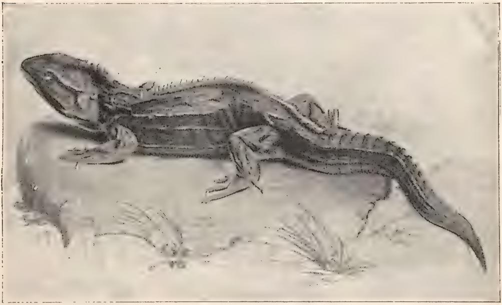


Fig. 109.—Tuatara.

NOTE.—The difference between reptiles and amphibians should be brought out during the course of the lessons. These distinguishing characteristics will not at first appear obvious to children, and for this reason in many of the text books on object-lessons the Frog is described as a reptile. Just as amphibians are distinguishable from fishes mainly in the structure of the limbs, in the absence of fins bearing fin-rays, and in the manner of respiration ; so reptiles differ from amphibians in the method of breathing and in the manner of development. The Frog obtains a supply of oxygen by means of lungs and through a moist skin ; a reptile breathes by lungs only. Again the Frog passes through a course of development known as a *metamorphosis*, during which it obtains the necessary oxygen through an arrangement of gills ; the reptile is developed from an egg, is born with lungs, and is furnished with gills at no period of its life.

The older pupils will be able not only to understand these differences, most of which should not be beyond the comprehension of any but the youngest children, but to appreciate the points of similarity between the three classes of animals.

The description given of the Common Lizard will apply with a few slight modifications to other forms. These when possible should be obtained and examined. The common lizard is easily procured and moreover can he kept in confinement sufficiently long to enable many of its habits to be observed.

New Zealand fortunately is almost free from reptilian life, so that any study of these animals beyond what is indicated in this chapter will have to be made by means of preserved specimens or pictures.

XII.—BIRDS.

INTRODUCTION.—Broadly speaking this class of vertebrates may be distinguished from the others by possessing a covering of feathers. All living birds are divided into two main orders: (1) those having a breast-bone provided with a keel; and (2) those having a flat breast-bone. To the former belong all birds capable of flight, and to the latter those unable to fly.

It is well in beginning the study of any class of animals, to select some particular form as a type and examine it closely. When this has been done other members of the class can be studied; and by comparing and contrasting the special characteristics of the different types much useful and interesting information may be obtained. A suitable type to begin on, and moreover one which is easily procured, is the Common Fowl.

The Common Fowl. The Common Fowl belongs to the order whose breast-bones are furnished with keels; it is, therefore, a flyer.

General Description. The body is ovoid in shape, tapering, in the living animal, gradually towards the head and tail. The fore-limbs, which in the other forms we have been studying served the purpose of fins or feet, are modified to form wings. These are set above the centre of gravity, and nearer the head than this region. The legs are fixed immediately below the centre of gravity, and hence in the best possible position to support the animal's weight. At the end of each foot are four toes, one of which is directed backwards; each toe ends in a single claw. The body is protected by a covering of overlapping feathers. Each feather has a free end and a fixed end, the former pointing towards the tail. The feathers, moreover, are light, warm, and smooth, and furnish the best of all coverings for animals adapted for flight. The legs are feathered to the end of the second joint, and the feet are covered with scales. The wings and tail bear a number of large feathers, which are used by the bird when flying.

The Head. The head is small and tapering, and ends in a sharp, arched, and horny bill, the upper mandible of which projects beyond the lower one. The eyes are large and round and placed at the side, so that the animal is obliged to turn its head in a curious way when looking at an object on the ground. The eye is closed by an upper and lower eyelid. There are no external ears, but a little below each eye a small opening occurs leading to the internal ear.

The Wing. Each wing consists of three main segments, (*a*) the upper arm; (*b*) the lower arm; (*c*) the wrist and hand--the latter bearing three digits seen when the feathers are removed. (See fig. 110)

When at rest these segments can be folded up and made to lie close to the body. The large quill feathers are fixed to the fore-arm and wrist and hand, and the wing is controlled by powerful muscles attached to the keel of the breast-bone.

Hind Limbs and Feet. The hind limbs or legs are formed to support the entire weight of the body except during flight, and are for this reason very strong. The strength of this region (*i.e.* where the legs unite with the body) is further secured by the fusion together of a number of the vertebræ, which in the other vertebrate animals we have examined possess a certain freedom of movement. The hip-bones, moreover, extend much further forward than is the case in quadrupeds, and are firmly attached to the fused vertebrae. Like the wing, the leg also consists of three segments corresponding to the thigh, the shin, and the foot, in such an animal as the rabbit. **The feet,** which are covered with scales, end in four toes, three of which are in front, the fourth being directed backwards. This arrangement is common to all birds which perch, enabling a secure foothold to be obtained. The long jointed toes are armed with powerful blunt claws admirably suited for scratching. Above the back toe is a short stout conical spur.

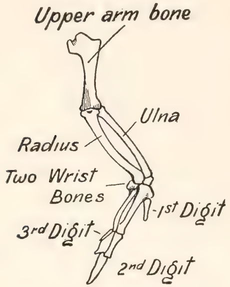


Fig. 110. - Fore-limb of flying bird, showing three main segments.

1. Upper arm bone. 2. Lower arm bone, consisting of ulna and radius. 3. Wrist and hand, consisting of two wrist bones, bones of hand, and three digits.

The Tail. At the end of the tail a number of vertebræ are fused together forming what is known as the ploughshare bone, which supports the long tail feathers. Above the end of the tail-region is a small rounded swelling, the oil-gland; from this the bird obtains a supply of fluid, which it uses when preening its feathers.

The Feathers. A plucked Fowl will show that the feathers are confined to definite areas on the body.

Certain parts of the body do not bear any feathers, but are covered by those on the "feather tracts."

The feathers may be grouped as (1) **quill-feathers** or those carried by the wings and tail, and hence used in flight; (2) **clothing-feathers**, sometimes called contour-feathers, or those provided for the purpose of keeping the bird warm, and giving rise to those beautiful curves, which add so much to its grace and symmetry; (3) **down** or small-feathers below the clothing-feathers, which aid still further in keeping in the warmth. These are well seen in water-birds such as the Duck, Goose, and Swan.

An examination of a quill-feather will bring out the following details. The lower parts consist of a hollow horny **quill**, which is prolonged into a solid flattened **shaft**, from either side of which springs the **web** or **vane**. The outer surface of the vane is smooth, shiny, and slightly convex, the inner surface being relatively rough and concave. The **shaft** at its junction with the quill bears a small tuft of down. The vane is made up of a number of flat rod-like projections, the **barbs**, which spring from either side of the shaft. These in turn consist of numerous delicate threads, the **barbules**, placed on the barb in much the same way as the barbs are arranged on the shaft. Each barbule is furnished with a hook and flange, and the whole are arranged in such a way that the hooks of one row of barbules interlock with the flanges of the next row. By this simple expedient the vane maintains an unbroken surface, the wind being unable to force the barbs apart.

The Air Supply. The work performed by birds in flight is perhaps greater in proportion to their size than that of any of the other vertebrates. A man, when taking violent exercise, requires to breathe quickly, i.e. he has need of an increased supply of oxygen; it is not surprising then that birds should be provided with breathing facilities which enable them to replace with great rapidity the large supplies of oxygen necessarily used up. The breathing organs are not confined to the lungs. The wind-pipe leads to a number of air-chambers, which supply air to all parts of the body. The bones, too, are hollow and communicate with the air-chambers; so that the air drawn into the wind-pipe, quickly finds its way to any part of the animal—hence the exceeding warmth of a bird's blood. This arrangement of air-chambers and hollow bones by making the body more buoyant is of great service in flight.

Habits. The Common Fowl is a ground bird, seldom flying unless hard pressed—it is, moreover a social bird, preferring to live with a number of its own kind. It spends most of its time in scratching up the ground in search of food, which consists of worms, insects, seed, and grain. Its feet are specially adapted for scratching, a statement which all whose gardens have been invaded by fowl will readily admit. The food is picked up by means of its horny bill and passed into a large bag at the bottom of the gullet calledthe **crop.** Here it is softened for some time before passing into the stomach, where it is further ground up in that portion of the stomach called the **gizzard.** This is a body with thick walls, and a hard tough lining and contains small pieces of grit which are swallowed, in order to assist in the grinding process. At night the bird roosts on a perch, which is firmly grasped by the toes. If not trained to go to the nest prepared for her, the hen lays in a nest of her own making in some sheltered spot. The loud cackling cry she utters after laying is familiar to any poultry keeper. When the eggs are laid, she sits on them for twenty-one days. At the end of this time the chickens appear fully fledged and able to fend for themselves.

When she has a brood of chickens, the hen is particularly fearless, being ready to defend them with great courage. She is able to call them with a peculiar clucking cry, the sound being capable of much variation. The chickens readily understand the meaning of the different sounds. A note of invitation where she has found some dainty morsel is quickly responded to, and, at the first warnings of a danger-signal, the brood hurry to take refuge under her wings. At night she protects them from cold by her warm covering of feathers.

Uses. Fowls are kept for the sake of their flesh as well as for their eggs. If well-fed and looked after, a hen will lay upwards of 200 eggs in a year. During the last few years the N.Z. Government has endeavoured to encourage the rearing of fowls, by introducing valuable breeds of poultry, as well as by facilitating the export of poultry and eggs. For this and other reasons the fowl-rearing industry has rapidly increased throughout the colony, and promises to furnish in the years to come a large and important export.

The Duck. The Duck may be taken as a type of that order of birds which spend much of their lives on the water, and are known as swimmers.

The body of the Duck is long and boat-shaped, being specially adapted for the life it leads. The short strong legs are placed as far back as possible, causing a peculiar waddling gait as the bird walks along. The three front toes are united by webs, and the hind toe is placed above the plane of the others.

The Head is curved on the top, and ends in a large broad and somewhat depressed bill, having a hard horny tip. A soft layer of skin covers both mandibles, each of which has along its inner edge, a row of tooth-like projections : the tongue is large and fleshy, and provided along its edges with a kind of fringe. Both the fringe of the tongue and the tooth-like processes of the mandibles serve the purpose of strainers and help the bird to secure its food. The neck is long and flexible and can be thrust out in all directions in search of food.

The Feathers which clothe the body are dense and glossy, and smeared with an oily substance which renders them waterproof. A layer of soft warm down covers the skin. The tail is short.

Mode of Swimming.—Note the shape and position of the legs. They are placed in such a way as to bring the propelling power into a position where it will be most effective in forcing the animal through the water.

In swimming the stroke is made by first drawing the foot forward, when the toes close and the webs are folded together so that the minimum amount of resistance is offered to the water. The back stroke is made by spreading the toes out and hence unfolding the webs, placing the legs in an oblique position and forcing them backward so as to strike the water with the broad expanded surface of the foot.

Food.—The Duck lives on soft vegetable substances, as well as on worms, insects, and other small animals. These are taken into the mouth with the mud and ooze, which are got rid of through the processes along the edges of the bill, and the fringes of the tongue.

Uses.—The Duck is highly prized not only on account of its flesh, but also for its eggs. Considerable trouble is sometimes experienced in training Ducks to lay in specially prepared nests; the birds generally prefer to lay in some secluded spot of their own choosing, or even on the bare ground away from the nests provided.

NOTE.—Probably no class of animals will interest children more than that of birds. They are everywhere familiar objects, whilst the wonderful power of flight, the gracefulness and symmetry of form, the beautiful voices of the song birds, the bright plumage and wonderful habits of many, form a combination of characters which never fails to stimulate the imagination and awaken interest.

In the great majority of cases there will be no difficulty in getting pupils to observe the habits of fowl. Most of those living in the country come from homes where fowl and ducks are kept, whilst those in town have not to go far in order to reach a poultry yard.

The Hen should be studied from living and dead specimens—one of the latter should be plucked in order to show the feather tracts and the structure of the fore-limbs, as also to allow the bony framework to be felt through the skin.

There is no actual need for a skeleton. The position of most of the bones can be made out through the skin, and a sufficient number of detached typical bones for examination purposes can always be secured: *e.g.*, backbone shewing fused vertebræ, ploughshare bone, breast-bone, bones of the limbs, etc. The same remarks, it is needless to say, apply equally to the Duck.

Whenever it is possible, a feature of these lessons should be **outside** observation. That is, pupils should be taken out to learn the habits of the birds by watching them amidst their natural surroundings.

XIII.—INTRODUCED WILD BIRDS.

The Song-thrush. This bird has found its way over the greater part of the colony, so that opportunities for investigation are almost everywhere available. It is moreover amongst the best known of the introduced songsters, and, as the bird is not specially shy, its habits can be observed without much difficulty.

The Thrush is a finely shaped bird from 8 to 9 inches long, with an olive brown back, grey throat, and spotted breast. The male and female are very much alike, the female being rather smaller than the male and having a paler breast.

The food of the Thrush is obtained for the most part on the ground,—where it hops along on a pair of stout legs,—and consists largely of earthworms, slugs, snails, and insects. It is of great use to the gardener in devouring insect pests and slugs, though it helps itself freely to ripening fruit and grain when these are available. The four toes of the feet are specially adapted for enabling the bird to maintain a tight clasp upon any object serving as a perch.

In this country the song of the Thrush is heard nearly all the year round. From early morning until late in the evening it sings—perched on a high bough, it pours forth a strain of joyous notes which in sweetness and melody few birds are able to surpass. In the cold of early spring its welcome song gladdens our hearts as a herald of the warm summer days.

The nest of the Thrush is built in a hedge, shrub, or tree—it is a massive structure, round, deep, and open at the top. The inside is lined with mud presenting a hard smooth surface, very like the inside of a cocoanut. The bird usually lays from four to six eggs. These are about an inch long, sky-blue in colour, and covered with black spots, which increase in number at the larger end. As in the case of most birds which build round nests, the eggs are placed with their narrower ends pointing towards the centre, an arrangement which enables them to be closely packed and more easily covered by the bird, and which is of advantage to the young bird when emerging from the egg—the exit being usually made at the thick end.

The hatching process lasts for about a fortnight. The young birds are at first blind and almost naked; they grow rapidly and are soon clothed with a warm covering of feathers. At the end of three weeks' time or less, they are sufficiently strong and well-grown to leave the nest. The old birds continue to look after them until they are able to take care of themselves.

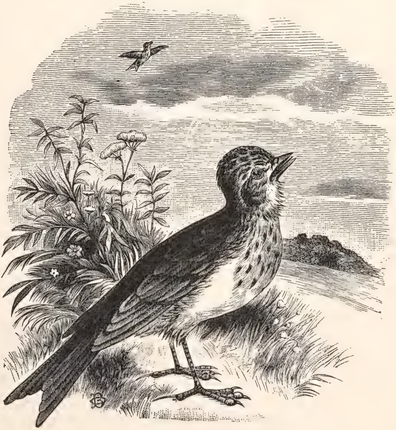


Fig. 111.—The Skylark.

The Sky-lark. The body of the Sky-lark is brown, with a light-grey throat, and breast marked with brown spots. The wings are long and streaked with black. Altogether the colouring of the bird is such as to resemble its surroundings, and serves a very important means of protection.

Its **feet** differ considerably from those of the Thrush—the toes lie flat on the ground, the back toe ending in a long claw. The bird is evidently adapted for a life spent mainly on the ground, and is rarely seen resting on a perch. It does not hop along like the Thrush or Sparrow, but runs like the Starling or Domestic Fowl.

Its **food** consists of worms, insects, grubs, and seeds—most of which it obtains when running on the ground, though it is often seen pursuing and catching insects on the wing. The service it does in destroying insects and insect-larvæ is almost incalculable.

The following extract from a recent publication admirably expresses the marvellous power of flight and song possessed by this bird.

"For its music alone the song of the lark is almost the most melodious of any bird's. The tone and quality are admirable, and the volume of sound astonishing. It can be heard clearly when the lark has mounted, as it some times does, beyond recognition by normal eyesight. The volume of sound is also most noticeable when a caged Lark is heard, singing, as it does, far nearer to the hearer than the bird in the sky. But apart from the quality and music of the song, the circumstances in which it is uttered render it an astonishing feat. Every other considerable songster is quite aware that singing entails much physical effort. Consequently it takes care to secure a good platform to sing from. A Thrush or a Blackbird nearly always selects a top shoot, or projecting bough, preferably a dead one, on which it sits and sings, never moving its position, and without any objects round it to hinder the 'carry' of its voice. But to the strain on its lungs of long-protracted song the Lark adds the great muscular exertion of a steady upward flight, usually carried out, not by scaling the air in gentle circles, as in the soaring of the larger birds, but by a vertical climb made by the incessant beating of its wings. Wordsworth's recognition of it as the—

> "Type of the wise who soar, but never roam ;
> True to the kindred points of Heaven and Home!"—

is often almost literally correct. After two or three spirals, the bird goes up almost as if it were drawn heavenwards by a cord, and then, closing its wings, descends like a falling stone to the very point from which it rose. The strain upon the muscles and the lungs would be great if during all this time it were silent. But it chooses to add to the exertion of soaring that of pouring forth a continuous flood of sweet notes, with no intermissions or breaks whatever. A Lark will soar and sing during a space of ten minutes consecutively. The rapidity with which the pectoral muscles are working during this period may be judged from the fact that the birds make not less than from five to six beats of the wing per second. The beats are usually in sets of from three to five, the bird pausing for a moment as if to take a fresh start after the interval."

The nest. There is always something very pleasing in the sight of a Lark's nest. It is usually sunk in a hollow of the ground or built in a tuft of grass, and, unlike the nests of many ground-building birds, is made with considerable care, the cup being deep and perfectly circular, and lined with fine dry grass. It is moreover difficult to find—indeed it is but seldom discovered except by accident, as for instance when the fields are mown. The nest is seldom made near the margin of a field where the bird might be disturbed by passers-by. Sky-larks have usually two broods in the year, and lay from four to five eggs —though four is the usual number.

The eggs are greenish-grey in colour and marked with light brown spots. The female bird sits on the nest while the male looks for food, some of which he carries to his mate, or sings his glorious song as he mounts and soars in the air.

NOTE.—We have now to a great extent done with the structure of these animals, that is, the plan on which the bony framework is put together. There may, indeed there probably will, arise occasions when it becomes necessary to refer to this matter, but these will not often occur, and, besides, need not demand exhaustive treatment. Pupils will now be concerned more about the habits than the build of birds, and, as these can be learnt only away from the schoolroom, much of the work outlined in this chapter will probably take the form of "talks" to pupils either in the class-room or during the progress of a field excursion. Specimens, either stuffed or living, of the forms dealt with, as well as good pictures and drawings, should be utilised if the work is done indoors. Children are keen observers, and, under encouragement, when opportunities offer, will themselves find out quite a great deal about the habits of the commoner birds. The information thus obtained can be elicited and expanded during the progress of a "talk," a form of lesson in which children are immensely interested.

Bird-nesting, it is unnecessary to add, will not require any encouragement. In boys it is natural, and inherited from a line of ancestors, leading back to prehistoric times. Indeed, it should be distinctly discouraged, as also the habit of collecting eggs, of which some young people are so fond. It is the kind of place the bird builds in, the kind of nest it makes, the number and size of the eggs laid, with their characteristics and generally protective colouring, towards which attention should be directed. A collection of eggs in a school museum may be useful, from time to time, for reference, and may serve to illustrate lessons on shape, size, and protective colouring; but it represents a good deal of thoughtlessness, possibly of cruelty, towards defenceless and useful creatures.

The great service which birds do in destroying insect and other pests, and so befriending the farmer and gardener, should be brought home to pupils. Considerations of this kind may help to check the natural desire on the part of some young people to empty the nests and carry off the spoil.

XIV.—NATIVE BIRDS.

PART I.

The Tui.

Amongst the best known of the New Zealand songsters is the Tui. In the early days of the Colony, before the bush was removed and settlement assumed its present dimensions, Tuis were very plentiful in all parts of the country; so much was this the case that Tui-pie was a favourite dish with the early settlers. The natives, too, were very fond of the Tui's flesh and showed great cleverness in capturing the bird, a skilled fowler being able to secure as many as a hundred in a day. Their

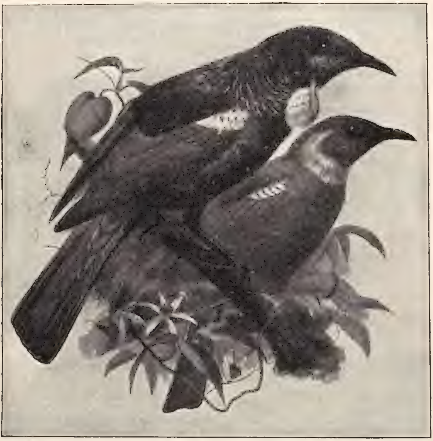


Fig. 112.—Tui, old and young.

numbers now have sadly diminished, though they are still to be found in most patches of bush.

The Tui belongs to that order of birds whose toes are specially adapted for perching.

The bird is somewhat longer and larger than the common Song-thrush. In colour it is bluish or greenish black, with white streaks on the back of the neck, and a white spot on each wing. On the throat are two tufts of white curly feathers, which are in strong contrast with its otherwise sombre plumage. It is to this adornment that it owes its name of the "Parson bird." Its eyes are large, round, and dark brown. Its legs are moderately long and stout, and, as in the case of other birds belonging to the same order, end in three jointed toes in front and one behind. The bill is long and curved. Both sexes are alike. The young are slaty black with a white patch on the breast, and without the white tuft on the throat.

The food of the Tui consists largely of berries and honey—the latter it obtains by thrusting its long beak into the nectaries of flower-bearing plants. It is particularly fond of the flowers and fruit of the Puriri tree, and of the flowers of the Wild Fuchsia and Kowhai from which it is able to obtain supplies of sweet juice.

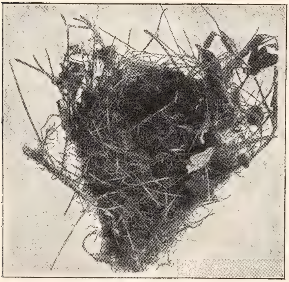


Fig. 113.—Nest of Tui.

The nest, which is large and shallow, is built of slender twigs and moss, and the down of the tree-fern, the whole being lined with fine grass. There are generally four eggs, white or pale pink in colour, and marked with brown spots, which are more numerous near the thick end.

The Tuis are amongst the most lively birds of the New Zealand bush and are constantly seen darting about amongst the shrubs and trees. A writer in an early number of *The Ibis* thus describes the Tui's manner of mounting into the air in fine weather in parties of about half a dozen, "turning, twisting, throwing somersaults, dropping from a height with expanded wings and tail, and performing other antics, till, as if guided by some preconcerted signal, they suddenly dive into the forest and are lost to view."

The Tui is a good songster, but can seldom be induced to sing; it seems to prefer mocking other birds, an accomplishment at which it is an adept. Its song is very melodious and sweet and such is the volume of sound when poured forth, as it usually is, from the top of a tall tree, that it is clearly heard for long distances round.

The Pied Fantail (Tiwakawaka).

Another well known native bird belonging to the same order is the Pied Fantail. It is found all over the Colony and is amongst the prettiest and most engaging birds in these islands.

The head and neck are blackish grey, with white throat and eyebrows: the back is brown, and the breast and abdomen are yellowish red. In the tail the two middle feathers are black with white tips, the outer ones are white, whilst the intermediate ones are white with the outer vanes partly black. All the shafts are white; the eye is round and black. The male and female bird resemble each other exactly. In the young the upper surface of the body is shaded with red and the lower surface with tawny brown. The legs are of medium length and slight and the toes are adapted for perching. The beak is soft, short and broad, the gape stretching nearly to the eyes, a great advantage to a bird living on insects, most of which are caught on the wing.

Fantails are most industrious birds, showing great perseverance and energy in building their nests, which are placed near large supplies of insects. Captain Hutton, in *The Animals of New Zealand*, writes on the subject as follows. "A bough standing from a high bank of a shady creek is a favourite spot. The foundation of the nest is laid by adroitly securing chips of decayed wood with lines of cobweb to the spray selected. This delicate operation must necessarily be a work of great difficulty. In places where splinters of decayed wood are not obtainable, pieces of coarse grass have been used instead. Fine grasses, thread-like roots, dead leaves or skeletons of leaves, hair, green tufts of moss, and the down of ferns are also brought into

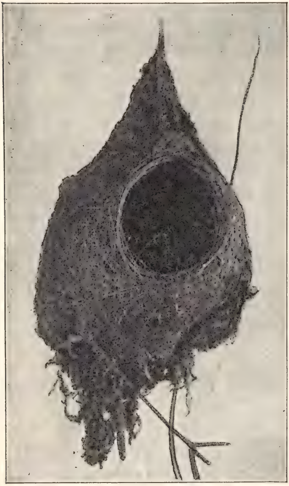


Fig. 114.—Nest of Pied Fantail.

requisition. Both male and female take part in the work, but the latter seems to bear the larger share. The strength of the structure is tested in many ways. It is trampled down, and the webs are carried from the interior to the outside in festoons from left to right, and right to left, as far down as the beak can reach. The wall gradually rises and the bird, with elevated tail, is itself the mould by which the rounded cavity is shaped. Seated in the centre of the rising structure, it turns repeatedly, fluttering its wings and keeping the wall pressed out to its proper shape. Its head and chin are pressed on the top, and the materials are pulled in towards the centre. This manœuvre is repeated at frequent intervals. So earnest are the workers that for hours together they scarcely rest. Sometimes by a flutter they obtain a few insects, or the creek is visited for water. The Fantail is one of the latest birds to retire to roost, his peculiar twitter being heard long after all the other birds have become silent."

The food consists chiefly of insects, most of which are caught on the wing.

The Kingfisher (Kotare).

The Kingfisher belongs toan order of birds differing from the one we have been considering in many important particulars. He is found almost everywhere in both islands and is well known to everybody.

In size the Kingfisher is rather smaller than the Blackbird—the body is long, the head and bill are large, and the legs and feet weak. The colouring of the feathers is extremely brilliant, the top of the head and the upper part of the back are green, whilst the lower portion of the back is a bright blue. The wings and tail are a glossy dark blue. A band of yellowish white encircles the neck and extends to the upper portion of the breast—the lower part of the breast is marked with brown. The sexes are alike—the young are brown above with a few white feathers on the back of the neck. The bill is long, stout, pointed, and compressed; indeed the size of the head and bill give the bird a clumsy appearance.

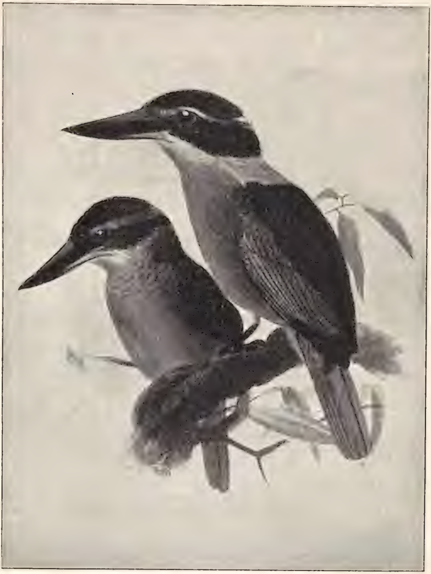


Fig. 115.—Kingfishers, male and female.

The European Kingfisher lives entirely on fish; but the New Zealand birds will eat mice, insects, crustacea, and even young birds.

Perched on a bough near a stream, the Kingfisher will spend hours watching the waters close by, apparently an uninterested spectator of his surroundings. "He seems to have no more serious business on hand than to display his gaudy plumage in the sun. Suddenly however all outward signs of mental activity vanish; a few rapid strokes of the wings, and, with his spear-like bill thrust well forward, and his wings tucked in, he darts through the air, a living flash of light, touches the surface of the water and secures the fish for which he has waited so long. A sudden twist, a few more rapid strokes of the wings, and he returns to land with the prey, knocks it on a stone or other hard substance until it is dead, or squeezes it to death between his powerful mandibles, and then swallows it whole, most likely head first."

Our Kingfisher, like other members of the family, is a grave, sedate, mournful, and usually silent bird. Even when not engaged in fishing, it often sits motionless without uttering a sound. It never delights to flit about in the trees, as if happy in existence. It has no real song; and its cries are monotonous and harsh, and without any sweet music.

The Nest is generally tunnelled into a bank, wall, or tree. The tunnel is about sixteen inches long, and two inches in diameter at the entrance. The floor of the tunnel rises from the entrance, and leads to an inner chamber about seven inches long and five and a half inches wide, while the height from the floor to the roof is four inches. This is the egg-chamber. It is hollowed out slightly below the floor of the tunnel, so that neither the eggs nor the young, when they are first hatched, can roll out and meet with accidents.

The birds usually lay from five to seven eggs and breed twice a year. The eggs are white and a little more than an inch in length.

The young stay in the nest until they are ready to fly well. When a site is finally selected and the work fairly started, the birds do not leave the spot, but one keeps watch when the other is working or is seeking food. The material is dug out with their bills, which they use as picks.

They will tolerate no intrusions into their home and resent trespassers even in the vicinity. The female has often been seen to meet a person two or three hundred yards from her young, dash at the intruder, return to the place where the young were perched, and repeat the attack several times.

Kingfishers are very useful birds, destroying many injurious insects, and thus rendering valuable service to the farmer.

The Kaka.

The Kaka belongs to that order of birds which includes the parrots and other climbers. It is found in both islands; but is almost confined to those places where the bush is dense.

In colour it is olive brown, with a grey head and purplish red breast. At the back of the neck is a band of yellowish red, and the under surface of the wing is red. The eye is dark brown. The bill is strong and hooked, the upper mandible being prolonged into a sharp curve, which projects beyond the straight lower one. The tongue is thick, fining down towards the point. The wings are long and pointed, and the tail is squared at the end. The short stout legs end in four pointed toes, two of which are in front and two behind, as in all climbing birds. The eyes are alike, and the young may be distinguished by the brown bars across the red under-surface of the wing.

The Kaka is very playful, very sociable, and very noisy. Living on and among trees it remains in the forest all the year round. When disturbed it hops about the branches with some dexterity, beak and wings assisting its awkward but rapid progress as it threads its way amongst leaves and sprays with unruffled plumage. The peculiar formation of its grasping feet enables it to perform wonderful feats of agile climbing. A sharp note or two marks its uneasiness when a vigilant eye watches what takes place below. When really alarmed, after a few hurried movements it flies a short distance away, at first usually gliding downwards rather than flying straight, threading the leafy margin of the close-growing trees with perfect ease and grace. At this time it warns its fellows of impending danger by uttering loud cries of Kaka, Kaka! which are often repeated. In its habits it is

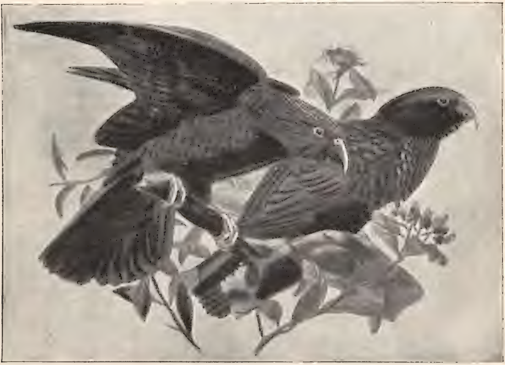


Fig. 116.—Kea. Kaka.

gregarious, and it is sociable even in distress, large numbers gathering round a fallen member of the company with apparent demonstrations of commiseration. This habit led to scores being killed where otherwise only a single bird might have been victimised. When migrating from one part of the country to another, Kakas fly at a considerable height. They do not travel in large flocks, from two to half a dozen being the usual number. When a pair of Kakas have mated, they are seen constantly together; if one moves from a tree, its partner quickly follows. For its nest the Kaka usually selects a tree with a heart that is quite decayed and having a convenient opening leading from the outside to the bottom of the hollow. The interior may require some preparation and the entrance may need smoothing and enlarging. Four white eggs about an inch and three quarters in length are laid on the decayed wood and there hatched. Attachment to their young is a strong point with these birds. An old bird has been known to perish at the entrance to its nesting hole during a bush fire, where it remained to protect its young, though escape was easy.

In the summer the Kakas are occupied with the cares of providing for their young and protecting them. After the young are able to get along by themselves, as autumn advances, the old birds become very fat. In places where they are not much disturbed, Kakas show great inquisitiveness and absolute fearlessness.

Their food consists of honey, which they sip from the flowers, and insects. The latter they pursue with relentless energy, stripping the bark from the trees in their efforts to secure them.

The Wood Pigeon (Kuku).

There is only one species of Wood Pigeon in New Zealand, a beautiful shapely bird well known to all who have any acquaintance with the bush. In the early days

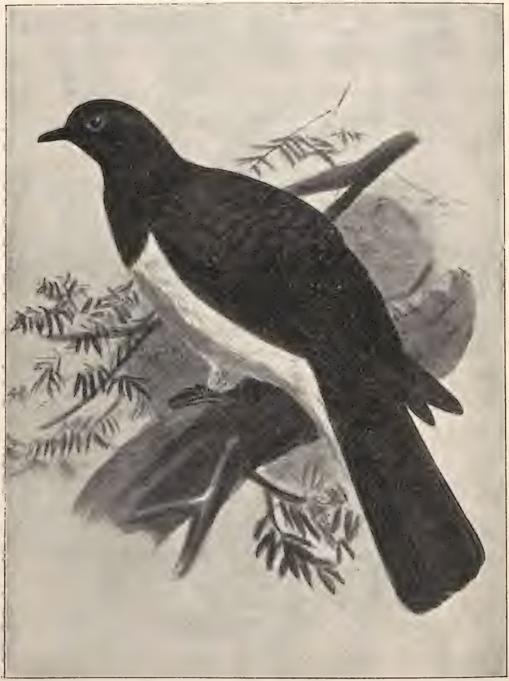


Fig. 117.—Wood Pigeon.

Pigeons were very plentiful in many localities where they are now but seldom seen. In certain places, however, they still occur in considerable numbers.

In colour the bird is coppery purple on the back, with head, neck, and breast of coppery green. The abdomen is white, and the tail dark green. The feet are pink, and the round, bright eyes are crimson.

The sharp bill arises from a soft swollen base, and ends in a hard tip. The feet end in four toes, three in front and one behind, all at the same level. The wings are broad and pointed, and the long tail is composed of twelve feathers.

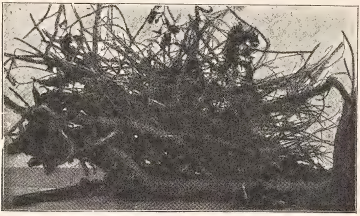


Fig. 118.—Nest of Wood Pigeon.

The Pigeon's nest is remarkably well constructed. The materials of the slight fabric, which appear at first to be rudely and carelessly placed together, are so nicely adjusted as to bear with perfect safety the weight of the heavy builders. In the slight depression of the platform the eggs or young lie undisturbed by the swaying caused by passing winds. There are usually two eggs, white and almost round, and nearly two inches in length. The young are at first quite helpless and unable to feed themselves; the parents supply them with a milky fluid secreted by their crops. When newly hatched the young birds are covered with soft warm down which gradually disappears as the permanent feathers increase in size.

The Pigeon lives entirely on fruit, the bush furnishing a plentiful supply of nutritious berries. Its flesh is very palatable, a fact which largely accounts for the rapidly diminishing numbers of this beautiful bird.

NOTE.—A good deal of what has already been said on the subject of birds applies to this and the following chapter; hence, although under certain circumstances useful and interesting lessons on native birds could be given in what are known as town schools, still the work is more suitable for country schools within reach of the bush, where the animals may be seen amidst their natural surroundings. When good living or preserved specimens are procurable, or where the school is within reach of a museum containing the forms under review, native-bird study should certainly find a place in the course.

Good pictures and drawings form a valuable aid, and should be made use of in illustrating and impressing points of importance.

Here, again, it is habits rather than structure to which attention will be directed; hence the work will deal largely with outdoor observations. This, as has already been mentioned, is the kind of work to which a study of bird-life, especially of native bird-life, most naturally lends itself; and it is just for this reason that birds and their habits form such an excellent and fascinating part of Nature-study. The observations made, in most cases, are altogether the pupils' own; and, although in the subsequent "talk" children may require assistance in correctly interpreting what they see, yet the consciousness of having found out something without aid from anyone will serve as a valuable incentive to further enquiry. The fact of the observations being undertaken voluntarily indicates the interest surrounding the subject, an interest, moreover, which will deepen as knowledge of the subject grows.

XV.—NATIVE BIRDS.

PART II.

The Harrier (Kahu).

The Harrier, better known as the "Hawk," belongs to the order known as **raptores**, or birds of prey. In the low open country in most districts he is constantly seen flying with lazy pinions near the ground, or soaring into the air.

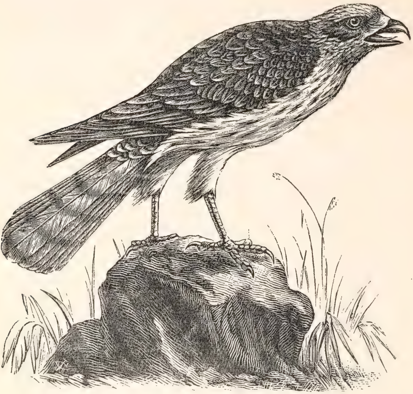


Fig. 119.—Harrier.

The body is long, light, and muscular, and, when the feathers have been removed, one is surprised at its small size. The upper part of the back is reddish brown in colour, whilst the part over the tail is a very light grey with a reddish bar near the tip of each feather. The tail is silver grey marked with brown bars, and the breast is creamy white crossed with reddish brown stripes. The brownish white of the thighs is marked with reddish brown streaks and spots. The head is low, somewhat broad, and depressed, and the eye is large, round, and yellow. The beak is hooked, the upper mandible projecting beyond the lower one in an abrupt curve, and ending in a sharp point. The legs are long and muscular and end in four toes, three in front and one behind, each of which is armed with a strong sharp claw. The Tail is relatively long and when expanded is almost square behind. The wings are large and powerful, reaching in average specimens from sixteen to seventeen inches in length.

In its movements the Harrier seldom appears to be hurried, flying slowly and noiselessly along the fern-clad ridges in search of prey. In its mode of pouncing on its prey it discloses peculiar craftiness. It will pretend to pass over its victim, then suddenly turn, wheel, and rush noiselessly to the ground. It plucks its spoil carefully, and picks the bones clean. It often visits the fowl-yard carrying off the young birds, and has been known to attack and capture full-grown fowls. Offal and garbage are its principal foods. One of its chief delights is to ransack a duck's nest, robbing and eating the eggs. Lizards, cicadas, grasshoppers, crickets, and other insects, as well as rabbits, rats, and mice, are also on its bill of fare.

The Harrier, though at times a troublesome marauder, is not a courageous bird. It has been known to be beaten off by the oyster-catcher, the gull, and even by a flock of sparrows.

For a breeding place the birds usually select a low-lying situation, among swamps, though nests have been found at considerable elevations where a patch of toi-toi grass and a few flax-bushes offered reasonable shelter. When the nest is approached, the bird does not attempt any defence but darts off uttering a shrill cry of alarm. There are usually three eggs; these are white in colour and about two inches in length.

The Morepork (Ruru).

Of the two Owls belonging to New Zealand the best known is the Morepork, so called on account of the peculiar cry it makes. Like the Harrier it belongs to the order **raptores,** or birds of prey. It is a small bird with a short round body, short neck, and a broad flat head.

In colour it is brown above with reddish brown spots, and below light brown marked with darker streaks. Its head is broad and flat, with large round bright yellow eyes, which are directed forwards and surrounded by a disc of soft light-grey feathers. The beak is short, stout, and hooked, and the nostrils are hidden by bristles. Both mandibles are curved, the upper one projects below the lower one and each ends in a sharp point. The legs are short, stout, and feathered, and terminate in four toes each of which ends in a sharp pointed claw.

During the daytime the bird spends most of its time in the gloomy shades of the bush. At night it comes out to hunt for prey in the shape of rats, mice, moths, insects and small birds. There were no mice in the country before Europeans came, so that the Morepork had to depend almost solely on small birds for its animal food, though it also fed upon grasshoppers, wetas, and other large insects. When disturbed in the daytime, it is dazed, and flies off to some shady spot, in an awkward and irregular manner.

The nest is made in a hollow tree or in hollow rocks in the bush: in it two or three eggs are laid—these are white, round, and about an inch and a-half in length.

The Pukeko or Swamp Hen.

This bird is one of the most handsome and graceful of the New Zealand rails. It is found in considerable numbers in swampy situations where the vegetation affords suitable cover and the moist ground furnishes a plentiful supply of food.

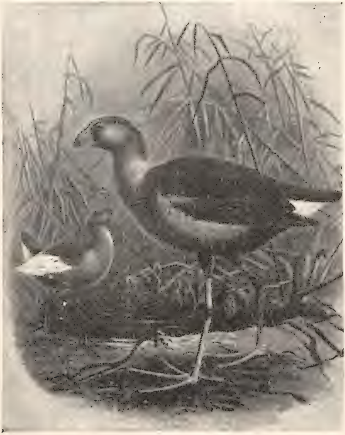


Fig. 120.—Swamp Hen.

In colour the back is bluish black, the breast indigo blue, the abdomen black, with a white patch under the tail.

The body is long and oval, ending in a relatively long neck and small head. The stout crimson bill is elevated at the base, widened on the forehead, and ends in a sharp point. The eye is well forward on the head and crimson. The legs are long, and hence well adapted for the purpose of wading, dark in colour and naked or almost so. The toes are very long, and free at the base.

The Pukeko spends most of its time on the ground, though is is often seen perched on shrubs or low trees, When hard pressed it can fly well; its flight, however, is laboured and awkward. When feeding it often lifts the food to its mouth with its claw as a parrot does.

It feeds chiefly in the early morning and in the evening, hiding itself away in the day time. Vegetable substances form its principal food, but it also eats insects. It is easily tamed, and when kept with domestic fowl makes friends with them. When it is walking along, its tail bobs up and down, allowing the white feathers underneath to be seen.

The **nest** of grass is built in swamps and is sometimes found quite surrounded by water. As a rule about five eggs are laid in the nest, but the number varies considerably. The young run about as soon as they are hatched, and, when disturbed, conceal themselves with much cleverness.

The Kiwi.

The Kiwi belongs to the second great division of birds viz., those whose breast-bones are not prolonged into a keel—such birds, we have seen, are flightless, and include amongst others, the Ostrich of Arabia and Africa, the Emu of Australia, and the extinct Moa of our own islands.

The Kiwi is the most notable living bird of New Zealand, and should be classed among the colony's treasured possessions. It has been aptly described by Dr. Wallace as one of the queerest and most un-birdlike of living birds. Sir R. Owen says that it seems to have borrowed its head from the long-billed waders, its legs from that order which includes the domestic fowl and other scratchers, and its wings from the Struthious birds, which include the Ostrich and Emu.

At first glance, the Kiwi's body seems to be covered with hairs instead of feathers; outwardly it has neither wings nor a tail, and the position of its nostrils at the tip of its long and slender beak, instead of at the base, constitutes one of its most distinguishing features. It has a keener sense of smell than is possessed by any other living bird. The eyes are small and inefficient. The ears are well developed and as an aid to discovering food are next in importance to its sense of smell.

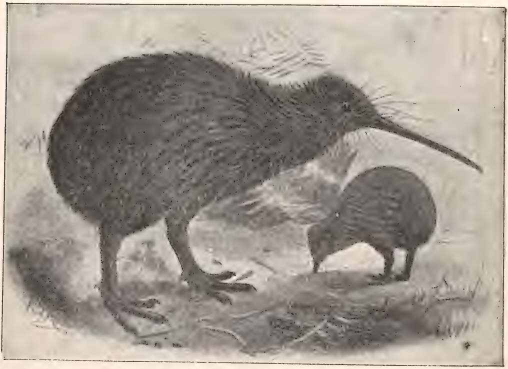


Fig. 121.—Brown Kiwi.

Along the feathers of the front part of its head are a number of long straggling hairs or weak bristles. These perform the useful office of protecting the eyes and head from injury and of acting as feelers, enabling the bird to thread its way in the dark. They serve in fact much the same purpose as do the so-called "whiskers" of the cat. The bill is long, tapering, and nearly straight.

The legs are short and stout, and end in four toes, three in front and one behind. The two side toes are equal in length, the middle toe being considerably longer than either. The hind toe is short and elevated above the others. At the end of each toe is a powerful claw which the bird uses in scratching.

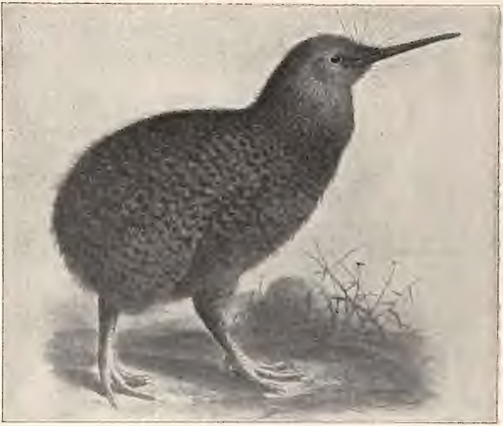


Fig. 122.—Grey Kiwi.

There are no large tail and wing feathers as in other birds, the whole body being clothed with small feathers, whose barbs are disconnected, a circumstance which gives the bird the appearance of being covered with hairs.

When the trunk is stripped of its plumage, the body presents the form of an elongated cone gradually tapering forwards, from the broad base formed by the haunches to the long thin beak, and the wings appear as two crooked appendages, projecting about an inch and a-half from the sides of the chest, and terminated by a curved blunt horny claw a quarter of an inch long.

For a nesting place the bird selects a hollow log or a hole amongst roots. Sometimes a hole is excavated in a soft bank, care being taken that the site selected shall be in a ridge of dry ground. Two eggs are usually laid, and the old birds rather lie than sit on them. Mr. A. D. Bartlett, superintendent of the Zoological Society's Gardens in London, as the result of experiments with a pair of Kiwis, states that "only the male bird sits on the eggs." The female is considerably larger than the male, and the egg she lays is out of all proportion to the size of the bird. An egg in the Canterbury Museum obtained from the West Coast measures $4\frac{1}{2}$ inches in length with a breadth of $2\frac{7}{12}$ inches.

The young have been described as "quaint-looking little animals with not too much of the savour of youth about them, being nearly exact miniatures of the adult."

There are four or five species of Kiwis. One, the Brown Kiwi, belongs to the northern portion of the Colony, and the others to the South. The feathers of the Brown Kiwi differ from those of the other species by being harsh to the touch.

The birds live in the darkest and densest forests, and at one time were plentiful in all the wooded portions of the islands. Now, however, they are exceedingly rare except in a few localities, their diminished numbers being brought about partly by the destruction wrought amongst them by Kiwi-hunters, and partly by the disappearance of the bush. During the day they repose in the forests, living beneath the long sedgy grass, or hiding in the hollows at the bases of lofty trees. At night, however, they leave their retreats and range about in search of food, which consists chiefly of worms and insects.

Characteristics and what they teach. A consideration of some of the peculiarities presented by the Kiwi are interesting as throwing light on the past history of the bird, and furnishing evidence of how the use or disuse of organs leads to their development or extinction.

The largeness of the egg is out of all proportion to the size of the bird, a fact which clearly indicates that the ancestors of the Kiwi whoever they were, were much larger in size than their present day representatives.

The remarkable fore-limbs were undoubtedly at one time true wings, bearing the feathers necessary for flight. In this connection it may be mentioned that a sleeping Kiwi assumes precisely the same attitude as an ordinary flyer, the head being thrust under the side feathers, between the body and the upwardly directed elbow; as though in former times the wings were made use of to cover the head and beak. There have been only two indigenous land mammals found in New Zealand, a Rat and a Bat, neither of which preyed on the Kiwi. The bird in fact led a life which in ancient times was particularly free from the attacks of dangerous enemies. There was little or no necessity for flight, so that the wings were gradually lost and became vestigial, from want of usage.

The eye of the Kiwi is small; this is surprising, for most nocturnal animals have large eyes suited for taking the utmost advantage of the semi-darkness. The Kiwi however finds its prey mainly if not entirely by scent, and has developed in consequence an extraordinarily perfect sense of smell. In past ages it had no need to keep watch against birds of prey, and as its eyes were not needed in looking for food, there remained little for them to see, hence they diminished in size and efficiency to a degree elsewhere unknown in the bird class.

Varieties of Birds. The foregoing deals in some detail with a few types of New Zealand birds. It might be found desirable to arrange these and others into certain groups noting the points of resemblance and difference. Some such arrangement as the following might be adopted either as a summary of what has already been done, or as a working scheme for lessons on bird life.

Climbing Birds. Two toes before and two behind, upper mandible longer than lower—Parrots and Cuckoos.

Perching Birds. Slender and relatively short legs; three toes before and one behind—Sparrows, Thrushes, Pigeons, Tuis, etc.

Running Birds. Strong legs, wings small and useless for flying—Ostriches, Emus, Kiwis, etc.

Scratching Birds. Strong legs, often covered with feathers, stout horny claws—Common Fowl, Pheasants, etc.

Wading Birds. Long and generally slender legs, bare—Pukekos, Herons, Bitterns, Stilts, etc.

Swimming Birds. Webbed feet, boat-shaped bodies —Ducks, Geese, Swans, Shags, Gulls, etc.

Raptores or **Birds of Prey.** Strong curved sharp bill, muscular bodies, strong legs, sharp curved claws, (talons)—Hawks, Owls, etc.

Birds of the district. It is hardly necessary to point out that, in any scheme of lessons, the birds of the district should receive special attention. Indeed it will probably be found necessary to confine the work at first to this particular part of the subject. Whatever is learnt should be by observation—especially in the initial stages—and this can be done in the case of dwellers in other districts or other lands only by having these in confinement, or by examining preserved specimens. As the work advances, however, it might be advisable to supplement what the bird-life of the district teaches by reference to other and similar forms found elsewhere. Lessons on the Harrier and Morepork, for instance, might well be supplemented by descriptions of other birds of prey, *e.g.*, the Eagle; but all such additional treatment, which after all must mainly be devoted to supplying information, should be well illustrated by sketches, pictures, and diagrams.

Birds and their Habits. In many schools useful and interesting work may be done by encouraging pupils to observe the habits of the commoner birds. The observations should be entered in special notebooks, and, moreover, should be made by the children with the least possible aid from the teacher. Pupils at first will no doubt require a little guidance in the matter of knowing what to observe, and this should not be withheld. Indeed, the object of the first lessons given should be to supply this training; but, once these initial stages have been passed, the rest should be left to the pupils themselves.

The following headings will serve as a guide to the kind of observations required:—

Kind of bird.
Whether gregarious or solitary.
    ,,   migratory or not.
    ,,   bold or timid.
Favourite haunts.
    ,,   feeding ground.
Food and how obtained.
Whether useful or harmful, with reasons.

Time of mating—kind of nest—where built—time taken in building — number of eggs — time taken to hatch—whether hatching done by one or both birds—time taken for young to grow up and leave nest—food of young, etc., etc.

XVI.—A BIRD'S EGG.

INTRODUCTION.—A bird's egg consists of a hard covering or shell inside of which are the white and the yolk—the former being colourless, and the latter yellow and opaque. As soon as the eggs are laid, the mother keeps them warm by sitting on them for some time. The effect of this being that the contents of the egg gradually develop into a young bird.

Shape and what it teaches. It is needless to say that much variety of shape is found amongst eggs. In some cases the eggs are spherical, in others almost cone-shaped whilst between these extremes nearly every intermediate form is found. The surface of the egg is everywhere curved, in other words the egg is always more or less round, a shape which has quite a number of advantages to recommend it.

(1) It is the most comfortable to sit upon—in no other shape could angular projections—more or less sharp—be avoided.

(2) It is the shape which gives the greatest strength to the shell—an important matter when we bear in mind the weight of the sitting bird.

(3) It is the shape which enables the bird most easily and safely to turn her eggs in the nest. The reasons for this operation will be discussed in the next chapter. It is carried out by means of the feet and beak of the bird, and,

but for the strong, roundish shape of the egg, would be attended with considerable risk.

(4) But few birds lay spherical eggs, the great majority of eggs being ovoid in shape--the form best suited for packing into a circular nest. This can readily be brought home to children by drawing a circle, dividing it into a number of sectors, and discovering by trial the shape which most completely fills each compartment. The eggs in an ordinary nest will be found on inspection to be packed with their small ends pointing towards the centre.

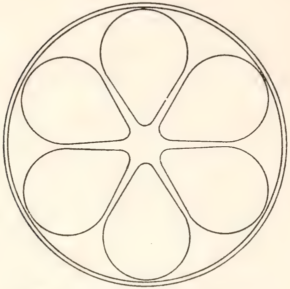


Fig. 123.—Diagram showing position of eggs in circular nest.

(5) It follows from par. (4) that since roundish eggs can be closely packed together, the roundish or ovoid shape is the one which enables the bird to cover her eggs most completely.

(6) If an attempt be made to roll a carrot or other cone-shaped body across a table, the difficulty of doing so will at once be seen. The object, instead of rolling along in some definite direction, will turn round the apex as though this point were fixed. A modified form of the same result can be obtained by using a typically shaped egg—unless pushed with considerable violence, there will be some difficulty in getting it to roll in a straight line. Conical eggs are usually laid in flat, open nests, exposed to the wind, and, but for the protection afforded by their shape, would be

in continual danger. Such eggs are laid by sea-birds and others which choose for a nesting place rocky ledges or even the bare ground. The ovoid shape then helps to prevent the egg from rolling out of the nest.

Size and what it teaches. Not only do eggs vary greatly in shape, but the size or volume of the egg also differs considerably; and by this is meant not so much that large birds produce large eggs and small birds the reverse—conditions we would obviously expect—but that birds of the same size are often found to lay eggs differing greatly in volume.

As a rule the young bird which comes from a large or relatively large egg laid in a roughly-constructed nest is covered with down, is able to run about in a few hours after leaving the shell, and before long can fend for itself. The nests in which such eggs are found are roughly constructed, for they are not required after the hatching is over On the other hand, comparatively small eggs laid in cosily built nests usually develop into blind, naked, and helpless young.

Then again, birds whose eggs are small generally lay a good number, and *vice versa.* The Wood Pigeon, for instance, lays from two to three, whereas the King-fisher or Fan-tail lays half-a-dozen or more. The explanation of this is simple. It would be useless for a bird to lay more eggs than she can cover; if, therefore, the eggs are large, the number which can be covered and kept warm must necessarily diminish. The Kiwi has much difficulty in covering two eggs owing to their size. Some seabirds are content with a single large egg, their manner of sitting preventing any others from being covered

Colour and what it teaches. All who have collected eggs will notice the great variety in colour in the different forms. The Pigeon's egg is white, the Duck's light green or blue; the Thrush's bright blue with black spots; the Lark's grey with darker spots; etc., etc. We have already seen that the colour of certain animals is of great importance in enabling them to escape from enemies. It is the same with the eggs of birds. Nests are robbed by rats, weasels, and by other birds—not to mention small boys, and thus protective colouring is of some importance. To fully realise the extent to which colour acts as a protection, the eggs must be seen amidst their natural surroundings. A Lark's egg for instance is not an inconspicuous object in a cabinet collection; but place it in the nest or on the bare ground and it is found only with much difficulty. Protective colouring is very characteristic of the eggs of all birds nesting on the ground; white or conspicuously coloured eggs are, on the other hand, placed in deep nests, hollow trees, or in places not easily reached. The Kingfisher for instance lays in a hole in the ground, the Owl ("Morepork") in a hollow tree, and the Pigeon in places almost inaccessible. Wild Ducks and Grebes which lay more or less in the open—cover up their eggs at the least alarm or before leaving the nest.

XVII.—A HEN'S EGG.

INTRODUCTION.—A hen's egg is really a packet of food to supply nourishment to the developing chick, and bears to the adult bird a relation somewhat similar to that of a bean seed or a maize grain to the adult plant. For the egg contains the germ of living matter which gradually develops into the perfect bird, just as the seed contains the life-germ which in time grows into the plant. And again, just as the seed in its endosperm or seed-leaves holds the food supply necessary to nourish the plant in its early stages of growth—so does the egg enclose the store of food without which the life-germ would be unable to develop into the young bird. These remarks apply of course to the eggs of all birds.

Shape.—The hen's egg is ovoid in shape—one end being distinctly more pointed than the other. The advantages of this shape have already been dwelt upon, so need not again be referred to. In colour the egg is either white or brown; its size, however, varies greatly.

The Shell is hard, brittle and smooth, and is composed of organic matter and lime salts—principally carbonate of lime. If a little hydrochloric acid be poured on the shell, the effervescence marking the presence of a carbonate can readily be seen. Running from the outer to the inner surface are a number of minute openings, *i.e.*, the shell, is porous. It is through these holes that the air passes which supplies the living germ with oxygen without which it could not develop into a young bird, and it is through them, moreover, that the impure air is got rid of. It is necessary that these pores be kept open; the presence of too much moisture would tend to injure the growing chick by closing up the pores. Eggs laid in damp situations, therefore, have a waterproof covering which admits of the passage of air.

If eggs are to hatch they must be cooled several times a day. Heat causes substances to expand and cold makes them contract. As the egg becomes warm from the heat of the sitting-bird, the air inside expands and is forced out through the pores. When the egg cools, contraction takes place, thereby lessening the pressure within, with the result that the surrounding air is forced inside—in this way a constant supply of fresh air is secured. It will be noticed than a sitting hen leaves the nest from time to time. This she does no doubt chiefly with the object of obtaining food, but her absence is necessary for the reasons stated above.

A small piece of shell is easily broken, but the shape of a complete egg so distributes the pressure, especia in the direction of the long axis, that it is able to withstand a considerable force without breaking. The shell must be sufficiently strong to bear the weight of the bird, and sufficiently brittle to allow the chick to break through.

Contents of the Egg.—The shell is lined with a thin white membrane—**the shell membrane**—which at the broad end is double, enclosing the air space or **air chamber.** The freshness of an egg is sometimes tested by holding it up to the light. If at the broad end a translucent space is seen, the egg is not fresh, for it has been laid sufficiently long to allow of the evaporation of some of the contents and the access of air which fills the air chamber. In a newly-laid egg the double membrane at the broad end is forced against the shell so that there is no air chamber.

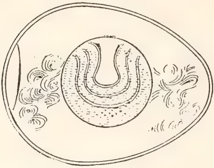


Fig. 124.—Section through egg showing flask-shaped mass or germ.

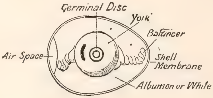


Fig. 125.—Diagrammatic view of a Hen's egg showing germinal disc.

Inside the shell membrane are the **albumen** or **white** and the **yolk.** The albumen is a clear, sticky and viscous fluid, which becomes solid and opaque on being heated. Its innermost part—or that immediately surrounding the yoke—is thicker than the rest, and is prolonged into two twisted cords the **balancers,** which gradually merge into the rest of the white and suspend the yolk in position.

The yolk is a yellow fluid contained in a thin elastic membrane which gives to this body a spherical shape. Like the white it becomes solid when heated. Under the yolk-membrane on its upper surface is a small circular patch somewhat paler in colour than the yolk, known as the **germinal disc.** This is the living germ from which the chick is developed; the rest of the yolk and the white are simply a store of food for the nourishment of the growing bird.

The germinal disc seen in the yolk is really the upper and expanded portion of a flask-shaped mass extending for some distance into the yellow fluid. Make a mark on the shell, place the egg in a vessel with the mark uppermost, and boil until it is hard. Remove the shell carefully and make a clean cut through the egg along the mark and the direction of the long axis. If the experiment be successful, the flask-shaped mass will be clearly seen with the open end of the flask uppermost, that is, directly under the mark previously made on the shell.

Function of the Balancers.—Make a hole in a fresh egg sufficiently large to enable the contents to be examined; the germinal-disc will be seen on the top of the yolk. Cover up the hole with a piece of gum-paper, turn the egg over and make another hole on the opposite side—the disc will again be seen on the top. Clearly since there is only one germinal-disc the yolk must have turned round inside the egg.

In order that the germ may grow into a chick it must be kept warm. The heat is supplied by the sitting bird, and that portion of the egg which is nearest to the bird's breast is warmer than the rest; hence the necessity of keeping the germ uppermost. If the egg be turned slowly, the yolk keeps pace with the movement and remains "right side up"—if, on the other hand, it be rotated quickly, the yoke gradually swings round into the proper position. Any sudden turning of the yoke, however, might injure the developing chick; this is guarded against by the balancers, which act as buffers and anchors, preventing concussion against the shell and securing a slow and gentle movement. The bird, as we have seen, is continually turning her eggs, with her feet and beak; hence the necessity of some arrangement which will prevent the contents from being injured.

The object of turning the eggs in the nest is slightly to alter the position of the chick from time to time and so to prevent the contents of the shell from interfering with its natural growth. Eggs kept in incubators without being turned either fail to develop or produce delicate mis-shapen chicks. Parts of the bird come in contact with the shell-membrane or other objects and having lain in the same position for some time, either grow to the objects or become mis-shapen; the germ develops into a weakly chick, which may be unable to break through the shell without serious injury.

NOTE.—A good deal of the work outlined in this chapter might be done out of doors, indeed it is best taken beyond the school walls. It has been placed after the chapters on birds so that the information collected whilst going through that part of the course might be available. Taken here it affords a useful opportunity for revision, as well as for gathering together and focussing the knowledge already acquired.

The methods of dealing with such a subject as a hen's egg are so obvious as to require but little further amplification. The whole of the investigation should be made clear by requiring each step to be seen and understood by pupils before passing on.

It is not desirable—indeed it is rather beyond the scope of primary school work to follow the development of the chick, so that all detailed mention of it has been omitted.

XVIII.—MAMMALS.

INTRODUCTION.—The following are some of the characteristics which distinguish this class of vertebrates from the others we have been considering.

(1) The young are nourished for a longer or shorter time by the milk or special secretion of the mammary glands.

(2) Certain parts of the skin are at some period of life provided with a covering of hairs.

(3) The crowns of the back teeth are frequently supported by from two to four roots.

(4) Closely fitting caps of bone, known as **epiphyses**, are nearly always present at the ends of the centra of the vertebral column. These but loosely united in the young, become fused to the centra in the adult.

The Rabbit: Classification. The Rabbit belongs to an order of mammals known as **Rodents**, so called from their habit of gnawing. This order includes Rats, Mice, Hares, Squirrels, etc.

General description. The Rabbit is a small animal, about the size of a cat, with a long body and relatively small head. The outside of its body is almost entirely covered with a warm coat of fur, consisting of two kinds of hair—coarse and fine. The coarser hairs are longer and fewer in number than the fine ones, the latter being closely-set over the body and protected by the former from damp and dirt. The long hairs, moreover, prevent the close soft hairs from becoming matted.

It might be well here to note the difference between **fur, hair,** and **wool.** Fur is soft and fine, and its great warmth is due to the air which is enclosed between its close fine hairs. Hair on the other hand is loose and coarse, and is not so warm as either of the other two substances. Wool is thick and matted, and like fur, is able to entangle a good deal of air—hence its warmth. Fur-bearing animals are generally exposed, owing to their method of life, to either mud or damp; yet in spite of this they are noted for keeping their coats clean and dry. The hair of the dog soon becomes wet and the wool of the sheep matted—the latter also retains a good deal of dirt.

The longest hairs on the Rabbit are its whiskers, which project from the cheeks, upper lip, and above the eyes. The whiskers are very sensitive—by means of them the animal can find its way along the narrow underground passages of its burrow.

Protective colouring. The colour of Wild Rabbits is greyish brown, for this is the colour which harmonises best with their surroundings. Rabbits are timid animals, and when in a wild state have a great number of enemies—any, therefore, whose colour is conspicuous have much less chance of escape than the others, and hence are not likely to leave offspring to inherit their disadvantages. The normal type of colour is the one which survives, the others gradually bring about their own destruction. Tame Rabbits on the other hand are not exposed to the same dangers, and variation of colour is frequently transmitted to the next generations.

The belly and under-surface of the tail are white. When the animal is feeding, the tail is kept down, but when flying from danger it is raised so as to expose the white under-surface, and to warn and guide others in their flight for safety.

The external ears are long funnel-shaped flaps of skin. These are very mobile and can be turned in any direction, enabling the animal to catch the slightest sound. When away from its burrow, the Rabbit erects its ears turning them constantly in all directions. If, however, the animal wishes to escape from observation by crouching on the ground, it lays its ears along its back.

The eyes are large and prominent, and placed on the sides of its head. In this position they are able to command a wide range of view.

Mouth and teeth. Rabbits are much given to gnawing young trees, being fond of the bark and soft tissue underneath. Tame Rabbits indulge their gnawing propensities by rasping away the wood of the hutch—though this can be of no use as food. The front of the palate is hard and rough, on the tongue is a hard pad, and on the inside of each cheek is a horny patch covered with hair; these protect the cheeks from splinters of wood and other hard substances which find their way into the mouth. The gnawing is done with the sharp front teeth called **incisors**, which project from the middle of the upper and lower jaw. These are four in number, two in each jaw, and are long and curved with exceedingly sharp cutting edges. A split or cleft in the upper lip enables the two upper incisors to be seen even when the mouth is closed. The cleft allows the upper teeth freer play, and enables the lip to be drawn aside, and so escape being injured during the process of gnawing.

The hardest part of the tooth, a substance called enamel, is at the front, and forms the cutting edge. Behind the enamel is a mass of dentine, which grows softer towards the inside of the tooth. This difference of composition results during the process of gnawing in the inner surface being most worn away, and the outer surface least—and thus a sharp chisel-edge is maintained. The teeth of rodents moreover grow constantly from the bottom, so that the upper surfaces when worn away are immediately replaced. Directly behind the two incisors of the upper jaw, is another and smaller pair, which can easily be felt by the finger. The enamel faces of these are directed backwards, so that the softer portions of the two sets of upper incisors face each other and are worn down to form a groove, in which the lower incisors work when biting. At the back of the mouth along each jaw are six **molar** teeth with uneven surfaces, used in masticating the food.

The neck is extremely flexible, and enables the head to be turned freely in any direction without the body being moved ; a matter of great importance to an animal whose life is in constant danger.

The limbs. Rabbits, as we have seen, are timid defenceless animals—so that their only chance of safety lies in flight. For this reason they are provided with limbs which enable them to run with great swiftness. The hind legs are much longer and stronger than the fore-legs, the former ending in five and the latter in four toes. The toes are armed with thick blunt claws which the animal uses in burrowing. The soles of the feet are hairy and so are able to maintain a firm hold on a steep or slippery surface. The great difference in the length of the fore and hind legs gives the animal a peculiar gait. It springs along the ground in a series of leaps, the long strong hind legs doing most of the work.

The tail is short and curls upwards ; it is greyish-brown above and white below.

Food and habits. The rodents are plant-eaters. Rabbits are fond of the tender succulent leaves of many kinds of plants, and like to strip the bark off young trees. Their feeding is done in the early mornings and in the evenings, when they are most likely to be safe from their many enemies. They are timid and defenceless creatures, and live in burrows or underground passages, which they excavate for themselves by means of their strong hind feet. They are moreover fond of living and feeding in company, and at the least sound of alarm scamper away to places of safety. When running from danger they expose the white underside of the tail which thus acts as a guide and signal to others. When startled or puzzled, they often thump the ground smartly with their strong hind feet in order to warn others who may be in the neighbourhood. They breed with great rapidity, it being estimated that from a single pair as many as a million descendants would spring in the course of five years, but for the many dangers to which they are exposed.

THE SKELETON.

The skull consists of a number of bones firmly fused together. At the sides are two large sockets for the eyes, and further back two flask-shaped cavities for the internal ears. The upper jaw is firmly fixed to the brain-case, but the lower jaw is hinged to the bony arches below the eyes. Each jaw bears teeth in a row of sockets. On each side of the upper jaw are two incisor teeth, and further back six molar or grinding teeth. The lower jaw carries on each side a single incisor and five grinding teeth, and can be moved both up and down and from side to side—as in the case of all plant-eaters.

The vertebral column, or back-bone, is made up of a chain of small bony rings or vertebræ, which extends from the back of the skull to the extremity of the tail; each vertebra consists of a solid central portion, from which spring several short processes differing in length in different parts of the vertebral column. On the front surface of the first vertebra, called the **atlas**, are two hollows into which two knobs on the skull are fitted. In the **neck** there are seven vertebræ—a number which remains constant in most mammals. Next to these come the **chest** vertebræ which carry the ribs, and further back still the large stout **abdominal** vertebræ. Between these and the tail-bones —indeed separating the two sets of bones—are four vertebræ fused together, forming a solid mass for the attachment on either side of the **hip-bones.**

The ribs are borne by the chest vertebræ—most of them curve round and unite with the **sternum** or **breastbone** in such a way as to form a cavity in which the organs of the chest are protected.

The fore-limb. The upper part of the fore-limb consists of a single long bone (the *humerus*) the upper end of which is rounded and works in a hollow socket at the front end of the **shoulder-blade**—a flat triangular bone overlying the chest. Connected with the humerus by means of a hinge joint are the two lower arm bones (the *ulna* and *radius*) placed side by side. Below these are two rows of small wrist bones (the *carpals*), and further on five rod-shaped bones (the *metacarpals* or bones of the palm). The fore-limb ends in four jointed digits or fingers.

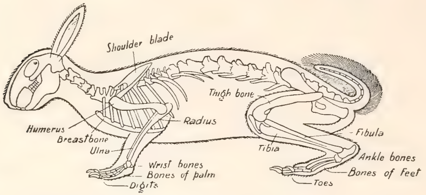


Fig. 126.—The Rabbit showing skeleton, or bony framework.

The hind-limb. The upper part of the hind-limb consists of a single bone (the *femur*), the rounded end of which works in a cup in the hip-bone. Below the femur and forming with it a hinge joint, are the two bones of the lower part of the leg (the *tibia* and *fibula*). These differ from the corresponding bones of the fore-limb by being fused together at the lower ends. Below these are the ankle bones (the *tarsals*), some of which are much elongated, and so provide additional leverage for the hind-foot. Below the ankle bones are the fine long bones of the foot (the *metatarsals*) each of which bears a jointed toe.

If the skeletons of a sufficient number of other mammals be compared with that of the Rabbit, the great similarity in structure between all animals of this class will be seen.

NOTE.—Any of the animals described under the heading of Mammals, will furnish material for lessons in any of the classes. Taking the Rabbit for instance—its general appearance and a few of the more obvious characteristics could be dealt with in the Infant Department. This could be followed by more detailed treatment in Standard I. and Standard II., with some account of its habits; whilst the higher classes would find plenty of work in a fuller investigation of general characteristics, structure, habits, and adaptation to environment, as well as in considerations involving comparisons and contrasts with other Mammalian forms.

It cannot be too frequently or too urgently insisted on that the objects dealt with should be seen and handled. Pictures and drawings, though valuable aids in all Nature-study, are but poor substitutes for the objects themselves.

It is not difficult to obtain a rabbit; indeed in many districts they are so plentiful as to be a source of much trouble to farmers, whose crops and grass they devour. A living specimen, as well as a dead one, should be procured for purposes of examination, most of which should be done by the pupils themselves. It sometimes happens that the teacher does all the work, at least all the important work, merely requiring the pupils to follow the process of investigation and acquiesce in the conclusions. Not only is this unnecessary—it is positively harmful, for it deprives the lesson of much of its educative value. Knowledge is to a very little extent real knowledge, unless it has been acquired by the knowledge-seeker himself. It is his eyes and brain and not the teacher's that must gather up the materials of thought, reason, comparison, contrast, and learn their utility and value in drawing inferences and reaching conclusions.

Pupils should be taught how to set about investigation, and so gradually learn to describe the object under review, with the minimum amount of direction and guidance from the teacher. They will rapidly acquire skill in this kind of work, which moreover will add considerably to the interest attached to the subject.

In dealing with the bony framework, a skeleton, though highly desirable, is not necessary ; a few typical bones of a Mammal—not necessarily those of a Rabbit—should be obtained and examined. The positions of many of the bones can be ascertained by feeling through the skin.

The habits of the animal with an account of protective colouring generally, will form a capital subject for lessons in districts where rabbits are plentiful. In this connection a good deal of independent investigation can be undertaken by the pupils themselves.

XIX.—THE CAT.

Classification. The Cat belongs to an order of Mammals known as **carnivores** or flesh eaters. Animals of this order have never fewer than four toes on each foot, all of which have claws—and these are generally capable of being withdrawn into sheaths. Other animals of the same order are Dogs, Wolves, Tigers, and Lions.

General Description. Cats possess the slender body characteristic of the carnivores ; for the flesh on which they feed is more easily digested than the food of plant-eaters, so that a simple stomach and short intestine are sufficient for the work of digestion. The big bodies required by the long intestines of the plant-eaters are not necessary in the case of animals living largely on flesh. The body of the Cat is covered with fur, consisting—as in the case of the Rabbit—of long and short hairs, the short closely-set hairs being below.

The Head is small and round—quite different in shape from that of the Rabbit. The external ears are short and erect, and the eyes, which are well in front of the head, are large and round. Growing from the bare patches at the sides of its mouth are a number of long hairs—the whiskers

These are extremely sensitive, and enable the animal to feel its whereabouts in the dark, in much the same way as the whiskers of the Rabbit assist it in creeping along dark narrow passages.

The Eyes. Cats are nocturnal in their habits; hence their eyes are very sensitive to light, the pupils becoming large or small according as the light is weak or strong. The pupil is really quite clear and transparent, and only *appears* dark because we are looking through at the black coat, **the retina,** at the back of the eye. Surrounding the pupil is a coloured ring, the **iris,** which regulates the supply of light by expanding or contracting. When the light is strong, this curtain grows larger reducing the pupil to a mere vertical slit; in the evening or at night, when it is of advantage to admit as much light as possible, the iris contracts and enlarges the pupil. We sometimes say that "cats can see in the dark;" by this we mean that they can see when there is too little light for us to do so—no animal, however, can see when light is entirely absent. The eye of the cat has a brilliant lining, which, reflecting the dim light of the evening, is able to reinforce the supply available.

The Ears, that is the external ears, are small and erect—and covered both inside and out with hair—that on the inside, however, being much less close than the outside covering. The sense of hearing is so keen that to steal upon a cat unawares is almost impossible. Pupils will know from experience how quickly a cat can hear the slightest sound.

The Teeth are sharp and pointed; in each jaw there are six small chisel-edged teeth, and two long curved canine teeth, one at each side, and four sharp molars. The molars, instead of being broad-topped like those of most mammals, have sharp cutting edges and overlap each other when the jaws are closed. The Carnivores do not masticate their food, but either swallow it whole as a dog does, or tear it up into small pieces and then swallow it. Vegetable food is not so easily digested as fleshy food, hence plant-eaters are provided with broad molar teeth with which they grind up the food into small pieces in order to assist the process of digestion. In the case of flesh-eaters the gastric juice—the digestive juice of the stomach—is very powerful and is able to carry on the process of digestion with but little assistance from the teeth. It is for this reason that the lower jaw of the Cat and the Dog can be moved only up and down—the side to side movement, being unnecessary, is prevented by the deep transverse sockets in which the ends of the lower jaw work. The jaws themselves are short and powerful, with a wide gape, which allows the cutting teeth to be set back, and gives plenty of scope to the long curved canine teeth in the process of tearing flesh.

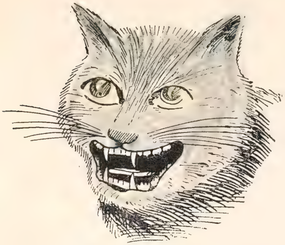


Fig. 127.—Head of Cat, showing teeth.

The Tongue is long and rough, its upper surface being covered with curved horny spines projecting backwards. These are used for stripping the flesh off the bones. Contrast with the Dog's tongue which is soft and smooth.

Sense of Smell. The Cat's sense of smell is small. If food be concealed by placing it under some loose covering—a piece of paper for instance—a Cat will probably be unable to find it. A Dog on the other hand has a keen sense of smell and is readily able to discover food if hidden in the same way. A keen sense of smell so essential to the Dog is not so necessary to the Cat, owing to its different method of hunting prey.

The Limbs are long and slender, and, broadly speaking, similar in structure to those of the Rabbit already described. The Cat is a toe-walker, and has padded feet. The fore-limbs have seven pads and end in five toes, each of which is armed with a sharp claw. The hind-limbs have five pads and four toes ending like the fore-limbs in sharp incurved claws. The claws moreover are retractile, and when not in use can be withdrawn into sheaths which entirely conceal them. The muscles controlling their movements are so arranged that when required the claws can be forced forward and buried with a stabbing action in the flesh of the victim. By withdrawing them into the sheaths the cat keeps its claws sharp, and, by allowing only the soft pads to rest on the ground, secures the quiet stealthy tread with which we are all so familiar. The curved claws are also used in climbing.

The claws are really finger nails or toe nails. The last bone of each toe is curved, pointed, and compressed. The edges of the nails are bent round until they meet, thus forming a claw enveloping the bone.

Capturing Prey. The Cat does not, like the Dog, run its prey down in the open, but either lies in wait or springs on it unawares at the end of stealthy silent stalking. Should this sudden rush and spring fail, the Cat rarely follows up its quarry, but waits for another. The silence of its movements is made possible by the rubber-like cushions on the under surfaces of its feet, as well as by the absence of projecting claws, and the rapidity and ease with which it springs forward are due to the immense leverage given by the arrangement of bones forming the limbs —especially the hind-limbs. The heel of the Cat is completely raised from the ground, being the projection at the back of the leg as shown. The knee is close up under the body, the thigh being enclosed in the skin enveloping the body. By this arrangement the long bones of the raised foot act as a third lever, and hence greatly increase the leaping power of the animal. Besides this the back-bone is extremely flexible and elastic, and when bent and then suddenly released, adds considerably to the force propelling the animal forward.

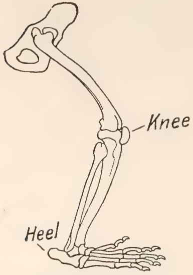


Fig. 128.—Hind limb of Cat.

The Cat after taking one of its immense springs; can alight on the ground without the least jar or shock, the fore-limb being jointed and bent in such a way as to prevent this.

The elbow is close under the body, the upper arm bone being buried in the body. When the animal alights on the ground, the elbow joint gradually yields to the impact, bringing the humerus and lower arm-bones closer together and so lessening the shock. The fore-limbs, moreover, have considerable freedom—there being no collar-bones, and the shoulder blade being loosely imbedded in the flesh.

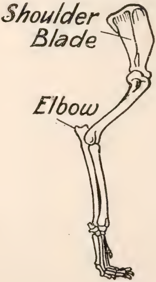


Fig. 129.—Fore limb of Cat.

Loose Skin. The skin of a Cat is attached to the underlying flesh by loose tissue, so that large folds of it can be pulled away from the body. The skin of a Horse or a Cow on the other hand grows closely to the flesh. To animals belonging to the same family as the Cat, a loose skin is of great advantage, as when seized it yields and is dragged round—the sharp claws being unable to obtain any hold on the flesh.

The Cat and the Dog—a comparison and a contrast.—These animals are so commonly kept as pets, and so well known, that they offer special facilities for examination. They possess, moreover, many points of resemblance, and at the same time differ from each other in so many particulars that they afford a useful exercise in the methods of comparison and contrast, which lie at the root of all successful work in Nature-study.

Covering.—The Cat's body, as we have seen, is covered with fur, whereas that of the Dog is supplied with a coat of rough hair. The fur of the Cat is dry, and being free from oily matter is soon injured by the wet—hence the animal's aversion for water. The hair of the Dog on the other hand dries quickly after being wet, and, moreover, is protected by an oily matter secreted by the skin. Then again the whiskers of the Cat are long—whilst those of the dog, whose mode of life does not require their aid, are comparatively short.

The Head of the Cat is short and round, whereas the Dog's head is long and pointed. In each case the jaws are armed with sharp powerful teeth—very similar in shape and structure—those of the Cat being sharper and more pointed.

The Eyes of both animals are round; but those of the Cat are more sensitive to light. The pupil of the Cat's eye, when exposed to a strong light, is contracted so as to form a narrow slit; the pupil of the Dog's eye is always round. Both have very keen sight, and rely on it in capturing prey.

The tongue of the Cat is rough and hard, that of the Dog smooth and soft.

The sense of smell in the two animals is very different. The Cat relies on its keen sight for finding its food, whereas the Dog's sense of smell enables it to follow its quarry by scent. The nose of the Dog, moreover, is much more moist than that of the Cat.

The limbs of the Cat, as we have seen, are bent and specially adapted for enabling the animal to crouch along the ground and reach its victim by an immense spring. Those of the Dog are much stronger and comparatively straight. In both cases the limbs end in the same number of toes, each of which is furnished with a claw. But whereas the Cat's claws are retractile, sharp, and suited for catching and holding its prey, those of the Dog are blunt and cannot be retracted: they are, in fact, suited for scratching. In both cases the under surface of the feet are provided with pads.

The body of the Cat is long and slender; that of the Dog longer and more robust, with a wide deep chest which affords greater lung power and thus fits the animal for the chase.

The method of capturing prey is different in each case. The Cat stealthily approaches its victim or lies in wait for it, and trusts for its capture to a swift rush or a long powerful spring. The Dog, on the other hand, runs its victim down, relying on its own speed and endurance and its keen sense of smell. Then, again, the Cat is distinguished by her slow and deliberate way of eating; whereas the Dog bolts his food with great rapidity.

The habits of the two animals shew a great contrast. The Cat is fond of warmth and likes to lie on the hearth-rug in front of the fire or in the sunshine. It expresses its pleasure by purring and by rubbing itself against persons and places. While it is true that some Cats evince great affection for particular individuals, they are as a rule more attached to places than persons. When lost, Cats can generally take care of themselves, and cases have been known of Cats leaving houses when they were well cared for and choosing to live a wild life in the bush.

The feelings of a Dog are expressed in its bark, in the way in which it wags its tail, and in the expression of its face. Dogs are unfitted for a lonely solitary life, and when left to themselves are apt to lose nerve. They are attached to persons rather than places, are amongst the most faithful of animals, and have become the companions of man in nearly all countries. They are extremely intelligent and can be trained to render great service to their masters.

Many of the habits of these animals are inherited from ancestors living under conditions altogether different from those of their domesticated descendants, and are to be explained only by considering the mode of life of their wild relatives. The Dog, for instance, turns round repeatedly before lying down. This is the remains of a habit acquired in past generations, when the Wild Dog, by turning round and round, smoothed back the grass and made a comfortable place to rest in. Again, the wild relatives of the Cat hunt singly or in pairs. The victim, on being killed, is devoured at leisure; hence the domestic Cat's slow and dainty way of feeding. Wild Dogs, on the other hand, hunt in packs, trusting to their numbers, speed, and sense of smell, to overhaul and kill the fugitive. When the prey is killed, it is torn in pieces and devoured greedily, each animal eating as rapidly as possible; for there is rarely enough to satisfy them all. Even the well-cared-for dog still shows his ancestral training by bolting his food.

NOTE.—But little need be added to the description given in this chapter. Like the Rabbit, the Cat offers a good subject for investigation in both Lower and Upper School. Little children, who are always curious about animal life, will find plenty to occupy their attention in examining the domestic Cat, whilst for older pupils the structure in greater detail, the habits, and the lessons to be learnt from inherited characteristics cannot fail to arouse interest.

A living specimen should certainly be utilised during the progress of the lessons; a skull or a jaw containing teeth will also be found useful. The bones can be felt through the skin, and their position and shape made out.

Lessons on this animal should be followed by others on the Dog, a description of which can be worked out on lines similar to those adopted in this chapter; after which a comparison and contrast between the two animals should not be overlooked.

The whole might with advantage be supplemented by "talks" on other allied forms—Tiger, Lion, etc. These, if well illustrated, will supply good material for conversational lessons, and help to deepen the interest in what already has been done.

XX.—THE HORSE.

INTRODUCTION.—The **ungulates** or hoofed mammals constitute the largest and one of the most important orders of which this class is composed. They are, broadly speaking, divided into two suborders, the **perissodactyla** or odd-toed animals, and the **artiodactyla** or even-toed animals. The former include the Horse, Rhinoceros, and Tapir, and the latter the Cow, Sheep, Goat, Pig, Camel, etc.

General Description. The Horse is a big animal, built for strength, endurance and speed, with a long rounded body, deep broad chest, slightly curved back, and powerful haunches. Its head is long and somewhat pointed towards the muzzle, and its neck is long and arched. Its legs are strong and tapering, each ending in one solid piece, the hoof. The skin is thick and covered with short hair, generally of uniform colour. The tail up to the root is furnished with long hair, and the upper edge of the neck supports a long flowing mane. There is also a growth of hair on the lower back surface of the legs. The ears are short and erect, and the eyes are placed at the sides of the head.

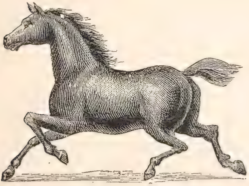


Fig. 130.—The Horse.

The long **head**, with its enormous mouth, is carried by the elongated neck arched on its upper side, and gradually getting thinner from the body to its junction with the skull. The length of the neck enables the animal to graze with ease, and also to command a wide view over its feeding ground.

The **lips** are thin and flexible and exceedingly useful in gathering food. This may be seen by the way a horse pulls hay from the manger-box or sweeps together the grass before biting through the stems.

The **teeth** evidently belong to a plant-eater. Each jaw carries six **incisors** in front, and twelve **molars** at the back, six on each side. Between the incisors and molars,

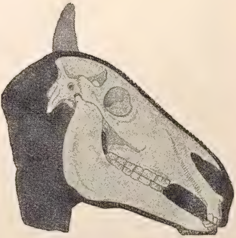


Fig. 131.—Skull of Horse.

on each side of each jaw, is a space free from teeth called **the bar.** It is into this space that the bit fits, where it can rest without causing inconvenience. Male horses have blunt canine teeth immediately behind the incisors.

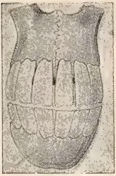


Fig. 132.—Incisors: front view.

The incisors are the same size in each jaw, and show an oval pit in the centre of the crown. It is by means of these teeth that the Horse is able to bite off the grass so close to the ground.

The molar teeth are large and broad, with ridges of hard enamel standing up above the general level, so that the upper surfaces are uneven and hence better adapted for grinding. It is with these that the food is ground to pieces, the process being assisted by a side to side movement of the jaws. The jaws of the Cat are able to be moved up and down only; those of the Horse and all other chewing animals possess the double movement just referred to.

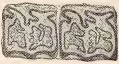


Fig. 133.—Upper surfaces, showing folding of the enamel and complicated structure of crown.

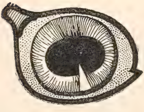


Fig. 134.—Eye, showing oblong pupil.

The eyes are large and prominent, with transversely oblong pupils, and are situated at the sides of the head, a position which admirably adapts them for seeing in all directions. The Horse in its wild state was a timid animal and relied for safety mainly on its speed, hence the necessity for discovering the approach of danger at the earliest possible moment. The inconvenience arising from the Horse's capacity for seeing all round, is obviated by the use of winkers. Its sight, moreover, is very keen—anyone who has done much riding will know how well it can see in the faint light of evening or even at night.

The ears are large and movable, either together or separately. This enables them to be turned in any direction, and so increases the power of hearing which, needless to say, is very acute.

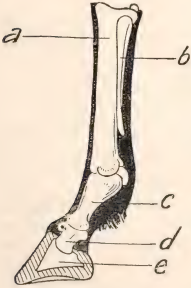


Fig. 135.—Lower part of fore-limb (side view).
a, cannon-bone; *b*, splint-bone; *c*, pastern bone; *d*, coronary bone; *e*, coffin bone.

The sense of **smell** also is very keen. To approach a horse unawares care must be taken to come up to it against the wind.

The limbs are extremely characteristic, being sufficiently strong to support a heavy body, and at the same constructed for speed. The fore-limb consists of the humerus, buried in the body of the horse, the **lower arm**-bones fused together and having the elbow close up under the body, the long **cannon**-bone below the knee with its two **splint**-bones, one at either side, and the three **small** bones at the bottom of the limb—the last of which carries the hoof. Comparing the fore limb of the Horse with the human arm—the similarity between the upper and lower arm-bones in each is obvious: the cannon bone corresponds to the middle metacarpal, or bone in the middle of the palm, and hence the knee joint of the Horse corresponds to the wrist. From this, it follows that the three lower bones in the limb,

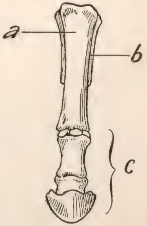


Fig. 136.—Lower part of fore-limb (front view).
a, cannon-bone; *b*, splint-bone; *c*, three joints of foot.

known as the pastern, coronary, and coffin bones, have their counterparts in the three joints of the middle finger. The last of these, the coffin bone, carries the thickened nail or hoof on which the animal walks. That is, the Horse walks—so far as his fore-limbs are concerned—on the nails of his middle fingers. The two splint bones are the remains of the second and fourth metacarpals, or of what in the human hand would be the two bones on either side of the middle bone of the palm.

The ancestors of the Horse, that is the animals from which the horse was evolved, were small creatures—about the size of a well-grown dog—with five digits on each limb, which lived in the woods and moist situations. In later ages the Horse roamed about on dry firm plains, and to suit its changed condition of life, its limbs gradually altered, bringing about the disappearance of certain bones and the modification of others, until, instead of five toes or fingers, it now has only one. It may be mentioned that the thumb of the hand is known as the first digit, and the little finger as the fifth.

In a similar way the reader, by examining the hind limb, will be able to determine the correspondence between the bones forming it and those found in the human leg or in the hind limb of the Cat or Rabbit.

This arrangement of bones by which the heel and wrist are raised from the ground gives three segments to the limbs instead of two, and, as each segment acts as a lever, greatly increases the propelling power of the animal. The elasticity of the joints above the hoofs prevents jarring or shock when the animal is moving along.

The edges of **the hoof** do not quite meet behind, the space being filled with a thick mass of tough skin somewhat softer than the hoof proper. This is the "sole" of the hoof and corresponds with the pads on the feet of the Dog and the Cat. Under the toe-bone and within the hoof is a soft cushion, and at the bottom of the hoof a tough outgrowth, "the frog." These elastic pads are extremely useful in lessening the shock of movement, so much so that, should the frog be cut away too freely, the bones and sinews of the limbs are apt to be injured by constant jarring. When the Horse is being shod, care should be taken that the nails are driven into the hard hoof and not into the enclosed sensitive tissue.

The nostrils are wide and fleshy, much wider and more distended than those of the Cat or the Rabbit. An animal, when taking violent exercise, requires a plentiful supply of oxygen, which in most cases can be inhaled through both mouth and nostrils. The Horse is unable to breath through its mouth, and as it is constantly moving with rapidity, and hence is in need of plenty of oxygen, it requires wide distensible nostrils. It will be seen from this how a vicious or struggling horse is sometimes subdued by being held by the nostrils. The animal is unable to breathe, and in a short time is forced to remain quiet.

The chest is large and deep so as to afford plenty of room for the large lungs. The Horse is a running animal and requires a capacious breathing apparatus in order to contain the large quantities of oxygen needed.

The food of the Horse is entirely vegetable, for, when allowed to feed at pleasure, it is essentially a grazing animal. Such animals have large stomachs and long intestines, for vegetable food does not as a rule contain so much nourishment as flesh, and is not so easily digested. This means that in order to obtain a sufficient supply of nourishment large quantities must be taken ; hence the necessity of a large stomach and long intestine with a big bulky body to contain them.

The tail is covered with long coarse hair, which forms an extremely useful " switch " for flicking off troublesome insects. For this reason it should not be cut back in such a way as to render it useless as a "fly-brusher." When this happens, the animal is obliged to protect itself from flies by incessant stamping and constant movement of the body.

Habits. The Horse in its wild state is fond of company, great numbers being often seen together. In its domesticated state it still retains this characteristic, preferring to live with others of its own kind. It has an exceedingly good memory. All who have travelled much on horseback will know with what wonderful accuracy it can find its way where perhaps it has been only once before and that a long time ago. It is quiet, obedient, and sensible, and one of the most useful of all our domestic animals.

In getting up on its feet after lying down, the Horse throws out the fore legs first and raises itself on the hind ones afterwards; whereas a Cow, resting on her knees, gets up on her hind legs first. In lying down the Horse lowers the fore part of its body and then the hind part. The Cow, on the other hand, supports herself on her knees until the hind part rests on the ground, before lowering the front part.

XXI.—THE COW.

INTRODUCTION.—The Cow belongs to a sub-division of the hoofed mammals, known as the *perissodactyla* or even-toed animals.

General Description. Its body is large and bulky, for the animal is a plant-eater, and requires, like the Horse, a long intestine and large stomach in order to digest its food. Its back is straight, and its small head, which is usually furnished with horns, is carried at the end of a short horizontal neck; contrast with Horse. Its legs are short, thick, and strong, ending in stout hoofs divided by a deep cleft down the middle, and are well fitted to support its bulky body. Under its body is a large bag, or udder, to hold milk. Its tail is long, and carries at the end a thick tuft of hair; contrast with the Horse and Sheep. The thick skin of the body is covered with Short coarse hair.

The head is small for the size of the body, with a broad flattened forehead and a square muzzle, and surmounts a short thick neck. The position of the head should be specially noted. Unlike that of the Horse, it is carried low.

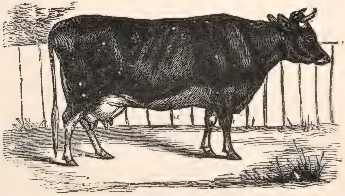


Fig. 137.—The Cow.

The ears are large, and can be quickly raised to catch the slightest sound. They are placed at the sides of the head, just below the horns.

The eyes are large and round, and situated well up on the side of the head, so that by raising its neck the animal can see well in all directions. The Cow is a timid gentle creature, and is furnished with ears and eyes so placed as best to detect the approach of danger.

The nostrils are large and gaping, for much the same reasons as apply to those of the Horse. The sense of smell, which also is keen, greatly assists the animal in avoiding danger.

The mouth and teeth. In front of the lower jaw are eight incisors, or cutting teeth : these bite against a hard pad in the upper jaw. At the back of each jaw, on either side, are six molars or grinding teeth. The herbage is pulled into the mouth by the long flexible tongue and mobile lips ; it is then held firmly by the lower cutting teeth against the pad, and half torn, half bitten off by a sudden jerk of the head. The molar teeth are made of substances differing in hardness, so that some portions wear away more quickly than others, thus giving rise to an uneven surface which greatly helps in the process of grinding. This is further assisted by the movement of the lower jaw, which is jointed to the upper jaw in such a way as to allow it to move both up and down and from side to side. The plant food, on which the animal lives, must be well ground up in order to be digested.

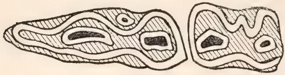


Fig. 138.—Molar Teeth, showing folds of enamel and uneven surface.

The cow a ruminant. After she has been feeding for some time, the Cow seeks a quiet comfortable spot and lies down. Here her jaws are seen to be moving as if they were chewing, and every now and then she gives a slight hiccough accompanied by a contraction of her flanks. Each time this is done, her mouth is filled with slightly chewed grass, which is slowly ground up between the molar teeth, and again swallowed. Another hiccough brings up a fresh lot of grass, which, in its turn, is gradually reduced to a finely-divided condition and then swallowed.

After the food has been gathered and roughly bruised by the molars, it passes into the paunch or *rumen.* This is a large bag for the storage of food, with a capacity, in the case of adult animals, of from 15 to 18 gallons. It is this part of the animal which is sold in the shops as tripe. From the paunch the food passes into the second stomach; this is a much smaller receptacle, having its inner surface covered with regularly formed cells, like the comb of the honey-bee, from which it has received the name of the **honey-comb** bag or **reticulum.** In this bag the herbage received from the paunch is made up into small pellets or cuds. When the Cow is resting, she forces these pellets up into her mouth, one at a time, as we have already seen, and thoroughly masticates them. This is called *ruminating*, or *chewing the cud.* Sheep, Goats, Deer, etc., are other examples of ruminants. When the cud has been well ground up, it is again swallowed, and passes along a channel into the third division of the stomach, called the **manyplies,** so named because it consists of a number of folds like the leaves of an uncut book. Here the food is formed into flattened portions by the action of the folds, and gradually passed outwards into the next stomach, the fourth, called the **reed** or **rennet,** where it is digested. The reed, then, is the true stomach.

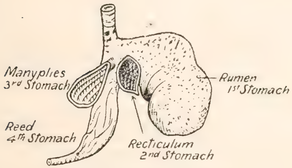


Fig. 139.—Stomach of Cow.

NOTE.—It is this part of the calf's stomach which is used in cheese-making. It forms an acid substance called rennet, which separates the milk into two parts—the **curd,** or solid part from which cheese is made, and the **whey,** or liquid part.

In the calf is a beautiful example of adaptation of structure to altered conditions. When the animal lives on milk, the first three stomachs are not necessary, as the food requires no preparation for digestion; hence, at first, the reed, or fourth division, is larger than all the rest taken together. As soon, however, as the calf begins to feed on solid food, the process of rumination begins, and the other three parts develop rapidly, until the rumen or paunch is larger than all the rest.

NOTE.—All horn-bearing animals are ruminants. This does not mean that all ruminants are animals with horns, for the Camel and Musk-deer are without them; but that the presence of horns indicates that the animal is a ruminant.

The horns. The top of the head is usually furnished with a pair of curved **horns,** which are really outgrowths from the frontal bones. Each horn consists of a hard bony core, and an outer horny case. The core is an outgrowth from the bones of the skull, and the case an outgrowth from the skin.

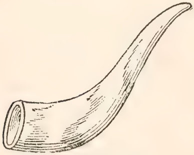


Fig. 140.—Horny Case.

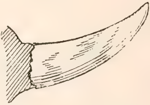


Fig. 141.—Bony Core.

The horns are the weapons with which the animals defend themselves from their enemies and fight with their fellows. It will be noticed that the horns of the Cow are much larger and longer than those of the Bull. This is because, when wild, it was the Cow who was most frequently called on to defend her offspring from the attacks of enemies, and hence she was the parent most in need of effective weapons.

The hoofs are divided by a deep cleft down the centre so that the foot consists of two toes, the inner surfaces of which fit closely together. It is usual to speak of the Cow's foot as "a cloven hoof," but it really consists of two distinct and independent hoofs, each of which is the thickened nail encasing the last joint of the digit. The digits which are left, in this case, are the third and fourth. In addition to the two "toes" on which the animal walks, there are two others which do not reach the ground (the second and fifth). Cows, then, are **even-toed,** like Sheep, Pigs, and Goats, whilst Horses, as we have seen, are **odd-toed.**

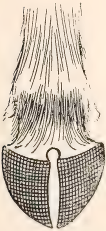


Fig. 142.—Fore-foot of Cow.

The Cow's natural home is on the low grassy plains or meadows, on which the yielding cloven hoof is best suited for running. The open cleft admits the air, so that the hoof is easily withdrawn from the soft ground into which it has sunk.

The tail, which is really a continuation of the backbone, is long and flexible, with a tuft of thick hair at the end. It is of great use to the animal in driving off the flies and other insects that settle on her body and worry her. When angry or frightened, Cows may be seen rushing across the meadows with their tails held out stiffly behind them. This is a sign of anger or fear, and serves as a warning to others; just as the bobbing of the Rabbit's tail warns its fellows of danger.

Uses. In some countries Oxen are used as beasts of burden, their strength, patience, and docility making them most valuable helpers to man. In this country they are frequently employed in hauling heavy loads, especially in the bush, where the soft yielding ground is unsuitable for the more powerful horse. A team of bullocks, moreover, will maintain a strong continuous pull, and thus are extremely useful in moving heavy weights from awkward positions. Cows are valuable for the sake of their milk. The Cow is naturally a forest animal, and, when wild, has often to wander long distances in search of food, leaving her calf, which is not strong enough to accompany her, hidden in the undergrowth. The calf is obliged to take sufficient nourishment each time it feeds to last for several hours, hence the necessity of a capacious udder to hold a large supply of milk.

When dead, various parts of the animal supply materials which it would be extremely difficult to do without.

The flesh is one of the best known foods, being both nutritious and easily digested.

The fat is also a valuable food. In addition to this, it is used for making soap and candles, and from it glycerine is separated.

From the *horns* many useful articles are obtained. Umbrella and knife handles are made from the solid tips, and drinking vessels from the hollow portions. Softened and spread out, the horns can be cut into combs and shoehorns, and, being translucent, the material is frequently used in lanterns, where its toughness often makes it a valuable substitute for glass. From the *hoofs*, softened in boiling water, buttons are cut; and from both hoofs and horns glue is obtained.

The bones, when cleaned and cut, are made into knife handles, umbrella handles, and numerous other articles. When boiled down, they yield jelly and glue, and, when burnt, they furnish animal charcoal, so largely used in the refining of sugar and in filters. The phosphorus required in the manufacture of matches is obtained from the bones, which also supply much of the bone dust so necessary to the farmer.

The hide, stripped of the outer skin and hair, and treated with tannic acid, is converted into leather, and the *hair* is used for making tar-cloth, for covering buildings, and lining walls and roofs.

XXII.—THE SHEEP.

Description. The Sheep is a hoofed mammal, belonging to the even-toed division of this order. It resembles the Cow in many ways—for instance, it is hoofed and even-toed; its head is frequently provided with horns; it is a plant-eater and chews the cud, and hence its teeth, stomach, and intestines are identical with those of the Cow. It differs from the Cow mainly in its size, and in the woolly coat covering its body.

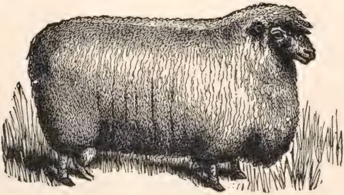


Fig. 143.—The Sheep.

The horns, with which the head of the male Sheep are usually provided, are directed backwards and then either twisted or spirally coiled. The animals use them as a means of defence against enemies, and for fighting with each other. They are carried by an immensely strong neck, so that rams are but seldom injured in their "butting" contests. The structure of the horn has already been referred to in a previous lesson (see page 239).

The size and what it teaches. Animals living in hilly country are usually smaller than those frequenting level country, and this is not difficult to understand. It is much easier to move a light body over hilly or uneven ground than a heavy one, for the heavier the animal, the more difficult, of course, is the work of climbing. Now, the Sheep is essentially a mountain animal, like the Goat, and in its wild state had its home in broken hilly country, where a larger frame would not only act as a hindrance, but would probably bring about the destruction of the animal. The Sheep is a quiet timid creature, and probably selected the mountains as a home in order to escape from the many enemies which would be likely to attack it.

The covering and what it teaches. The body of the Sheep is clothed with a covering of warm thick wool, which varies in length and texture with different breeds. The fact of the covering being warm indicates that the home of the animal was confined to cold regions, but the Sheep does not thrive in the far north, and the only other cold regions are to be found in lofty elevations, hence the woolly covering furnishes additional evidence that the Sheep was originally a mountain animal.

The fibres of wool, when examined under the microscope, are seen to be rough and scaly. For this reason they can be spun into threads of loose texture in which a great deal of air is entangled ; woollen garments are thus bad conductors of heat, and hence prevent the escape of warmth from the body. The wool, moreover, is greasy from a substance which is secreted by the skin, and protects the animal from rain.

The tail of the Sheep is short and woolly. The animal does not require a long tail like the Horse or Cow, as its fleece is a protection against flies and insects, as well as against cold.

The descriptions already given in the lesson on the Cow, of the horns, hoofs, and limbs, method of feeding, etc., apply to the Sheep as well.

Habits.—Sheep are gregarious animals—they like to go about in flocks, and, if not confined in small enclosures, will frequently wander great distances in search of food or a suitable locality to rest in. The members of a flock have a curious habit of following one of their number—the leader—following that is, not only the direction he takes, but imitating his movements as well. If a stick be placed so that the leader jumps over it—the others will do the same—sometimes they will continue to jump when they reach the place even though the stick be withdrawn. In a wild state, when escaping from enemies, the members of the flock were obliged to trust for guidance to those in front. In the race for safety it often happened that leaps were necessary—and as those behind were probably unable to see the obstacle, and, moreover, had not time to consider the situation for themselves, their only chance lay in following the example of their leaders. Hence a characteristic which has given rise to the expression "to follow like a flock of sheep."

The young of Sheep, the lambs, are, as every one knows, extremely fond of play. They are able, moreover, to run and keep up with their mothers, climbing steep hills and travelling long distances. It is for this reason they are provided with thick strong legs, which enabled them when in a wild state, to run with their parents and escape from danger; contrast with the Cow and her young.

The udder is relatively small, for the lamb, being able to run with its mother, can obtain milk from her at short intervals, hence there is no necessity for a large supply of nourishment being kept in readiness. Here again the cow and her young will furnish an interesting contrast.

What has already been said of the uses of the Cow will apply with slight modification to the Sheep.

NOTE.—The hoofed mammals are amongst the most useful animals employed in the service of man; it would be difficult to imagine what the world would be like if deprived of the benefits it enjoys from the presence of these creatures.

In dealing with the horse—or indeed almost any of the hoofed mammals—it is clear the animal cannot be brought into the schoolroom, and there are many schools where considerable difficulty would be experienced in taking the class to the animal. Still this could often be done in country districts where suitable opportunities will frequently occur.

In the absence of the animal itself, pictures and diagrams must be resorted to. But in the case of domestic animals, most of whom are well known and frequently seen, the presence of the animal itself is not essential. When using the pictures and drawings, constant reference should be made to the living form, and pupils should be encouraged to tell what they know of the matters under review. A jaw or an entire skull should be procured as also the lower portion of a fore-limb, showing the cannon bone, the bones of the foot, with the outer portions of the hoof. The horn of a ruminant with the outer casing as well as the bony core should also be obtained. In addition to these as many as possible of the products which come from the animal when dead, should be available for reference when the "uses" are being dealt with.

It is a mistake to think that these animals do not form suitable subjects for treatment in country schools, because children are so familiar with them. Indeed these are just the conditions under which they should be discussed. Children, though constantly seeing the animals, often know very little about them. The average child, if questioned about a cow, would probably exhaust its store of information, after having described the more obvious characteristics, and would have some difficulty in comparing and contrasting this animal with the horse with any degree of fulness. The fact is, beyond a few of their uses, and the best method of treatment, most people think but little about domestic animals.

Children in country districts know enough of their habits and build to appreciate and enjoy further enquiry.

An account of inherited characteristics should be reserved for the more advanced stage of the course. It is not intended that pupils should be *informed* of these, but that they be gradually led to recognise in them an explanation of observed facts. In other words the pupil should be brought to discover for himself the real significance of characteristics which represent conditions widely different from those which now prevail.

Lessons on the Horse and Cow might be followed by others comparing and contrasting these animals. So too the investigation of the Sheep might lead up to lessons on the Goat—which in their turn would prepare the way for other comparisons and contrasts.

XXIII.—THE PIG.

INTRODUCTION. The Pig is a hoofed mammal, and like the Cow and Sheep belongs to the even-toed division of this order. It differs from these animals in many ways—amongst others in being covered with a thick tough skin; and is for this reason placed with other thick-skinned animals—*e.g.*, the Elephant and Rhinoceros—in a division of the ungulates known as the **pachyderms.**

General description. The body is nearly cylindrical, tapering slightly from the shoulders, and supported on short stout legs. The head, which is long and pointed, is placed on the same line with the trunk, and ends in a broad tough disc (the snout). The skin is covered with stiff hairs or bristles, thickly planted, and the short thin tail is generally twisted or curled. The eyes are small

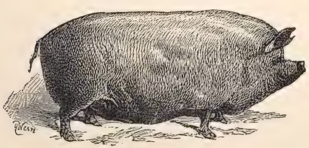


Fig. 144.—The Pig.

and deeply set, and the ears are large and upright. Each leg ends in four toes—the two front ones carrying hard horny hoofs on which the animal walks—the hind pair are smaller and do not reach the ground in walking.

Shape, covering, and what they teach. The domestic Pig is usually kept in a sty, and has no special need for a tough skin and tapering pointed body. In its wild state however, these are extremely useful, enabling it to burrow without injury through the dense and prickly undergrowth where the animal is usually found. The skin is further protected by a covering of stiff elastic bristles which grow thickly round the small deep-set eyes, and so guard them from injury. The shape and covering then tell us that the animal in its wild state lives in the bush or jungles where the thickets are dense.

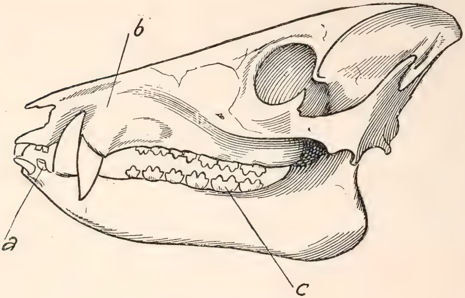


Fig. 145.—Skull of Pig.
(*a*) Incisor teeth; (*b*) Tusks; (*c*) Molar teeth.

The jaws and teeth. The mouth is large, and the immensely strong jaws are well furnished with teeth. In front are the sharp **incisors,** specially adapted by their shape for biting pieces from any large object, and being directed forwards can be used for pulling up plants or picking up small objects from the ground. Behind the incisors are four large sharp pointed **canines,** two in each jaw, which, in the boar or male animal, grow into great curved tusks standing out from the sides of the mouth. It is with these that he fights his enemies or digs for food, his large muscular neck enabling him to use his tusks with great effect. At the back of the mouth are the **molars,** which differ from those of the Horse and Cow. The molars of these animals have broad rough surfaces, suitable for grinding only—those of the Pig however are broad and rough at the back of the row, but short and pointed towards the front, as in flesh-eating animals.

Food. The Pig is naturally **omnivorous**—as is shown by its teeth—its food consisting practically of everything eatable, roots, plants of various kinds, insects, flesh of animals, and even carrion. With its tapering head ending in a broad disc of gristle supported by a special bone, it is able to turn up the soil in search of roots and worms. On the upper edge of the snout is a hard swelling, which greatly assists the animal in the work of grubbing. It is to prevent this that the farmer puts a ring through the nose; for the Pig, if allowed to run in the fields, can do considerable injury by rooting up the pasture land. The Pig is proverbially a greedy animal. The amount of food it obtained in its wild state varied considerably with the season; in autumn the ripe fruit furnished a plentiful supply—whilst winter meant a time of scanty meals. It was necessary therefore that when food was abundant the animal should get as much as possible in order to lay up a store in the form of fat, to carry it through the winter. The characteristic greed of the domestic Pig may be explained by the conditions under which it lived when in a wild state.

Owing to its readiness to eat almost anything, it is necessary that considerable attention be paid to the way in which the animal is fed. The flesh of the Pig may be rendered unwholesome as food by careless feeding. It is for this reason that many people are so particular in getting pork from butchers on whom they can rely.

The feet end in four toes, the two front ones on which the animal walks being protected by hard horny hoofs.

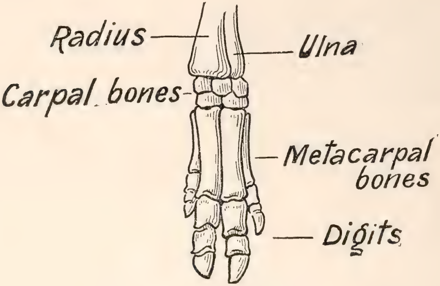


Fig. 146.—Fore-limb of Pig.

The hind toes, though longer than those of the Sheep, do not reach the ground, and are therefore of no use to the animal. They furnish in fact another instance of the disappearance of organs owing to disuse—see description of Horse.

The split hoofs are of great service when the animal is making its way through wet swampy ground, or rushing over the soft yielding soil of the bush. Even if we did not know in other ways, the cloven hoof would indicate the natural haunts of the animal.

A clean animal. Many people consider the Pig a dirty animal, but this a great mistake. Unfortunately the sties in which pigs are kept are often allowed to become filthy; but that is not the fault of the animal but of those who do not provide it with means of keeping itself clean. Even under unpromising conditions pigs will try to keep the sleeping place in the sty clean; and when wild, after wallowing in the mud, they have been known to wash themselves in running water, before lying down to rest.

The young. The number of little pigs appearing in a litter is great compared with the young of the Sheep or Horse. As a rule an animal which belongs to a large family born at the same time is exposed to a life of danger, hence the likelihood of only a few living to grow up. The larger the number born, the greater will be the chance of several surviving—it is for this reason that so many young ones appear in a litter. The little pigs, when born, are almost helpless and unable to get about—indeed it is some time before they can run with their mother, and for quite a long period of childhood they are exposed to danger. Contrast the Pig in this connection with the Horse and Sheep.

Uses. The flesh is used for food, either fresh, as pork, or salted, as bacon and ham. The skin can be tanned into a very useful leather (pig-skin) tough and durable, and largely used for covering saddles. The thick strong bristles growing on the back are used for making sweeping-brooms and various kinds of brushes, *e.g.*, hair-brushes, clothes-brushes, tooth-brushes. The shoemaker also makes use of the bristles in sewing; fastening one to the end of his waxed thread, he uses it as a needle.

PART III.

MINERALS AND ROCKS.

I.—MINERALS.

INTRODUCTION.—The earth's crust is composed of mineral matter collected together and solidified in various ways and included under the general name of rock. It is difficult, perhaps, to realise at first that the entire crust of the earth with which we are acquainted either consisted or does consist of rock or mineral. Such is the case, however ; the soil on the hills and plains, the sand on the sea-shore, the mud on the river-bottoms and harbour-flats have all been derived from the earth's rocky framework. Even the vegetable mould resulting from the decomposition of organic matter is indirectly indebted for its origin to the rocks.

The disintegration of rocks or the way in which the hard material of which they are composed is gradually converted into soil will be dealt with further on.

A rock is a mass of matter composed of one or more simple minerals, with a more or less irregular external form, and ranging in cohesion from loose debris to hard, compact, and close-grained stone. Granite, lava, limestone, sandstone, slate, shale, conglomerate, breccia are all examples of rocks.

As the rocks, themselves, are in nearly all cases merely aggregates of mineral matter, it is proposed before beginning a systematic investigation of rocks to examine a few of the commoner minerals.

Minerals. A mineral may be defined as a substance having the same composition throughout formed by natural means, *i.e.*, without the agency of man, and under conditions in which neither animal nor vegetable life has taken part.

This definition would exclude Coal, which by common usage is regarded as a mineral, and would include such substances as gases, water, and ice. For our purposes we shall certainly consider Coal as a mineral substance, though derived from the decomposition of organic matter, and shall, with the exception perhaps of Mercury, confine ourselves to the investigation of minerals which, under atmospheric conditions are solids.

It is sometimes stated that a mineral substance differs from animal and vegetable forms in that it does not grow. A young rabbit or a potato plant increases in size as it becomes older—whereas a mass of Salt or Limestone does not add to its volume as time passes. But in point of fact this is not the case. Under certain conditions minerals steadily increase in size; a fact which is capable of easy demonstration by allowing crystals of various substances to separate out from saturated solutions. Between the animal and vegetable kingdoms on the one hand and the mineral kingdom on the other, there are other differences besides those contained in the definition given above. A mineral increases by additions made to its exterior or outer surfaces. An animal or a vegetable grows by assimilation of matter which is taken into its interior. Again, animals and vegetables are bounded by curved or irregular surfaces, whereas minerals in their crystallised state, with one or two exceptions, are bounded by plane or flat surfaces.

Examination of Minerals. There are usually three methods employed in examining minerals—we may investigate their physical characters, their chemical composition, and their optical properties. The first two are the only ones capable of being undertaken in our primary schools, and of these the second can be employed to a very limited extent only.

Physical properties. These may be investigated under the following heads :

A. Properties depending on the reflection of light.

COLOUR.—A specimen may show some definite colour, *e.g.*, yellow, brown, black ; or it may change in colour when it is turned in the light, it is then said to be **irridescent.**

Quartz and Mica sometimes exhibit this property.

LUSTRE.—The lustre of a mineral must be distinguished from its colour; thus Galena or Sulphide of Lead is grey in colour, but possesses a metallic lustre, whilst Quartz may be colourless or white with a glassy lustre. The lustre of a mineral may be :

Metallic.—The ordinary lustre of metals. Galena, Gold, and Iron Pyrites are examples.

Glassy.—The lustre of glass. Rock-salt and Quartz are examples.

Pearly.—Like a pearl.

Resinous.—The lustre of resin. Zinc-blende and Opal are examples.

Silky.—Like silk. This lustre is confined to minerals having a fibrous structure, and is well seen in the fibrous forms of Carbonate and Sulphate of Lime.

Shining.—Having a smooth bright surface.

Galena and Iron pyrites afford examples.

B. Properties depending on the transmission of light. A mineral may be :

OPAQUE, when it transmits no light at all—*e.g.*, Coal, Galena.

TRANSLUCENT, when it is capable of transmitting light but cannot be seen through—*e.g.*, thin pieces of Flint.

TRANSPARENT, when objects can be clearly seen through it—*e.g.*, clear Quartz, Calspar, thin flakes of Mica.

C. Properties depending on molecular arrangement:

SECTILITY.—Minerals are said to be sectile when they can be easily cut with the knife—*e.g.*, Graphite, Selenite.

MALLEABILITY.—Malleable substances are those which can be flattened out under the hammer—*e.g.*, Lead, Iron, &c.

DUCTILITY.—A ductile substance is one that can be drawn out into wires.

Note.—The properties of malleability and ductibility belong to metals only.

ELASTICITY.—A substance is said to be elastic when on the bending force being withdrawn it springs back to its former position.

FLEXIBILITY, or the property of being bent.

BRITTLENESS.—A substance is said to be brittle when it tends to crumble or fly to powder on being tapped.

FRACTURE.—The appearance presented by the freshly broken surface is known as the fracture. It may be curved and in other ways **shell-like**; flat and **even**; or rough and **uneven**.

D. Characters depending on taste:—*i.e.* taste may be—
Saline. Sweet. Bitter. Sour, etc., etc.

E. Characters depending on odour.

F. HARDNESS.—This charactistic varies greatly and forms one of the most important tests in determining minerals. Thus Quartz and Calcite which are sometimes very much alike may at once be distinguished by the simple expedient of testing the specimens with an ordinary knife-blade. A portion of the Calcite can easily be scraped away, whereas the Quartz will be scratched only with difficulty.

The hardness of a mineral may be tested by rubbing the specimen over a file and noting the amount of fine powder and noise produced in the process. The softer the mineral is, the greater will be the amount of powder and the less the degree of noise.

A scale of relative hardness should be made out—indeed found out—before applying this test. Such a scale as that given in books on mineralogy is beyond the scope of the enquiry primary school children could be expected to undertake. A few of the minerals most easily obtained should, however, be operated on and arranged in a scale of hardness, which would serve as a basis of comparison when other specimens were being tested. Rock-salt, Calcite, Felspar, Quartz, are suitable minerals for such a scale.

In this connection, too, comparisons and contrasts are useful exercises. On being asked which is the harder—Glass or Iron—most children will answer "the latter," and, moreover, they will give as a reason for their opinion, that Glass is more easily broken than Iron. It is only after a good deal of questioning they are brought to see that brittleness and hardness are different properties, and that a simple way of determining the latter in the case of any two substances, is to scratch or endeavour to scratch one with the other.

G. FORM.—Whether crystalline or non-crystalline. It is not at all advisable to make the examination of minerals too complicated; hence teachers will do well to omit all consideration of the many terms that are employed under the head of form, and to confine the investigation here to the general shape of the mineral shewn and to its crystalline or non-crystalline character. Such distinctions, moreover, as those which are made between the terms **crystalline** and **crystallised** should not as a rule be attempted.

The particular forms of the crystals might be noted, but only when the more obvious forms are under review, *e.g.*, good specimens of Quartz, Galena or Calcite. To attempt anything approaching a systematic study of crystallography in these lessons would mean, amongst other things, the employment of a terminology which could result only in confusion.

H. CLEAVAGE.—The tendency to split along definite planes possessed by many crystals. Here again the amount of attention directed to this property will depend largely, if not entirely, on the specimens under review. The fact that some minerals split in certain definite directions leaving clean even faces, whilst others fracture with an uneven surface, will be quite enough to attempt.

I. SPECIFIC GRAVITY, or the weight of the substance compared with that of an equal bulk of distilled water at 60° Fahr. or 4° Cent.

Chemical properties. The investigation of the chemical properties of minerals might be confined to:

A. FUSIBILITY, or the property of melting. To melt a mineral substance a very hot flame will be required—so that this test can seldom be applied.

B. INFLAMMABILITY, or the property of uniting rapidly with oxygen and so burning.

C. BEHAVIOUR on the application of some acid, usually Hydrochloric Acid. Carbonates, when treated in this way, effervesce owing to the liberation of Carbon-dioxide.

Note.—Most of the carbonates are acted on very slowly unless the acid be heated.

Note.—This brief account of the properties which are to be looked for in minerals is intended as an indication of the way in which the examination of a mineral may he set about. It would be unwise in each investigation to apply all the tests suggested. With a little practice the properties likely to be found in the specimen under review will suggest themselves, and these, as well as others of which the investigator is doubtful, can be tested. It is not necessary, moreover, to test for the properties in the order given, so long as the properties themselves are discovered, it does not much matter in what order the discoveries are made. It will be found convenient to take certain groups of tests together—for instance, brittleness, hardness, cleavage will obviously form one group.

II.—COAL.

Introduction.—The word Coal is a popular, rather than a scientific, term, and is applied to a number of different substances which agree in being more or less pure varieties of uncrystallised Carbon, and which have been formed by the compression of old land vegetation into the material which is now used as fuel. Coal is not a mineral substance in the same sense as Slate or Marble, as it is of vegetable origin ; still its mode of occurrence and general properties cause it by common usage to be regarded as a mineral. A little thought will convince anyone that it is more convenient to include it amongst the minerals than amongst the plants.

Physical Properties.—Show a piece of common Coal, and let the pupils discover for themselves its physical and chemical properties.

They will begin by describing in general terms the **shape** of the specimen, *e.g.* its size, irregular surface, angular projections, etc., etc. This is a most necessary preliminary in all examinations of minerals, and should on no account be omitted. They will then note whether or not it can be handled without soiling the fingers. Some kinds of Coal can be touched without leaving a mark ; others readily soil whatever they come in contact with. Before making this test, care should be taken to brush off any dust adhering to the surface.

Its **colour** and **lustre** should next be dealt with. The black colour will be recognised in any specimen. The lustre, which varies with the kind of Coal, from brilliant or shiny to dull, can be seen properly only on a surface exposed by a clean fresh fracture. Pieces of Coal when taken from the seam at first have this shiny lustre ; but exposure to the air roughens the surface and in other ways causes the lustre to a great extent to disappear ; hence the necessity of examining a freshly-exposed surface. Pupils will at once recognise that the mineral is **opaque**, when reference to other opaque substances might be made. The necessity for doing this will depend on the intelligence and state of progress of the class. By tapping the specimen with some hard object or dropping it on the floor its **brittleness** will become apparent. A few other brittle substances, *e.g.*, Glass and Chalk, might then be examined so as to pave the way for a contrast between the properties brittleness and hardness, which should be made perfectly clear. In order to test its **hardness,** a knife or a file should be used—reference here might also be made to the scale of hardness—if this has already been dealt with. If not, the hardness of the mineral might be contrasted with that of other substances, *e.g.*, Chalk, Wood, Lead, Iron, Glass. This last substance will furnish a convenient material for bringing out the difference between brittleness and hardness. Glass and Coal are both brittle ; but the former is much harder than the latter ; for it can readily be made to scratch Coal.

A sharp tap with some hard substance—the same test in fact as that used for brittleness—will reveal the **fracture** of Coal, which in some cases is very characteristic. The specimen, when operated on, should be held in the hand; if placed on a firm object, when struck, the whole specimen may fly to pieces.

The **cleavage** of the mineral may be examined at the same time, though cleavage and fracture must not be confused. Cleavage is the tendency to split along definite planes and leaves smooth flat surfaces—fracture, on the other hand, may take place in any direction in the mineral, and generally leaves irregular surfaces exposed. Some varieties of Coal break with a distinctly **conchoidal** fracture, others when struck split up into cubical pieces. Chip off a piece of the specimen under examination and note carefully the exposed surface. If this shows concentric ridges gradually diminishing towards the point where the specimen was struck, something like the lines of growth of a bivalve shell, the fracture is said to be *conchoidal* or shell-like. If, on the other hand, fragments cannot be chipped off the specimen, but the whole tends to break up into pieces which are roughly cubical, the mineral does not show fracture but is said to possess cubical *cleavage.* Pupils will gradually come to see that, in the case of a fracturing mineral, a chip can be taken off practically from any convenient projection; but that cleavage is possible only along definite planes. A piece of Coal, for instance, that breaks into cubical fragments, splits along definite planes approximately at right angles to each other and can only with difficulty be made to break up in any other way.

Taste and **odour** might or might not be tested. Neither is important in the case of Coal, but it is as well that pupils should accustom themselves to using these tests so as not to overlook their application in cases where this becomes necessary.

That this mineral is **non-crystalline** can easily be seen by contrasting it with other mineral substances which occur in well-defined crystal form, *e.g.*, Quartz, Calcite, Galena, Iron-pyrites. Pupils will see that no approach to a crystalline structure is apparent in the case of Coal.

With the upper classes it might be worth while to work out the **specific gravity** of the minerals examined. Whether or not this is done circumstances must decide. If time permits and the class is well advanced it might, with advantage, be undertaken; if, on the other hand, as will probably be the case in most country schools, the time available is all too short, and two or more Standards are grouped for instruction, it had better be omitted. To find the specific gravity a moderately sensitive balance is required. The more sensitive the balance, the more accurate will be the result obtained. Still there is no reason why the investigation should be omitted, because of the absence of a delicately adjusted and highly sensitive pair of scales. The results will be utilised mainly for comparing the specific gravities of various substances, so that a fairly sensitive balance will find out the necessary information. Work of this kind is extremely useful if properly undertaken, *i.e.* if the pupils themselves be required to make the investigation, for it furnishes a training in accuracy of observation, in careful calculation and in the importance attached to detail—which must be of infinite value to pupils in after years.

The specific gravity balance here shown is easily used. The substance, being examined, is first placed in the scale-pan A, and carefully weighed. It is then hung on to the hook below the pan A, suspended in water, as shown, and again weighed—both results being carefully noted. By subtracting the weight in water from the weight in air, the loss of weight sustained by the substance when immersed is

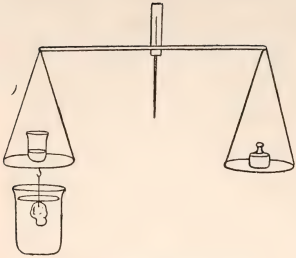


Fig. 147.—Specific Gravity Balance.

found. This corresponds to the weight of the water displaced, *i.e.* to the weight of a volume of water equal in bulk to that of the substance itself. We have now only to divide the weight in air by the weight of the water displaced in order to find the specific gravity.

A rough determination of the specific gravity of a piece of Coal gave the following result:—

Weight in air	$5\frac{3}{4}$ ozs.
Weight in water	$1\frac{1}{4}$ ozs.
Weight of volume of water displaced	$4\frac{1}{2}$ ozs.

$$\text{Specific gravity} = \frac{5\frac{3}{4}}{4\frac{1}{2}} = \frac{5{\cdot}75}{4{\cdot}5} = 1{\cdot}27$$

The reasons why such a method of procedure determines specific gravity belong to investigations usually undertaken under the title of experimental physics, which cannot be discussed here. The reasons, however, can be easily demonstrated by means of the same apparatus as is here employed, and should certainly be made clear to pupils before they are required to investigate the specific gravity of any special substance. If determination of specific gravity be omitted, the weight of the mineral compared with that of an equal volume of water should be ascertained by observing that Coal will sink in water. It is for this reason a moderately heavy substance.

Chemical Properties.—If there is a fire in the room, put a piece of Coal on and let the class describe exactly what takes place. The behaviour of the Coal will differ in detail with different varieties, but in all cases it will burn and not melt, from which we learn that it is **inflammable** and **infusible.**

To recapitulate: We have investigated the physical properties of the mineral under the following heads:—

General shape of specimen
Colour
Lustre
Power of transmitting light (opaqueness or transparency)
Brittleness
Hardness
Fracture
Cleavage
Taste
Odour
Form (whether crystalline or non-crystalline)
Specific gravity
Inflammability
Infusibility

It will be seen, on referring to Chapter I, that the investigation has touched on almost all the headings under which the physical and chemical properties of minerals may be considered. Some such method should in every case be adopted, in order that, as the subject progresses, comparisons and contrasts may the more readily be made.

Origin.—Though Coal consists of compressed vegetation, traces of organic structure can be seen only on careful examination. This, however, frequently discloses portions of stems, leaves, or carbonised woody fibre in the coal seam itself, and impressions of leaves and other parts of plants in the rocks casing or enclosing the seam.

Exposed to atmospheric conditions dead vegetation goes to form humus, and so to increase the soil. Withdrawn from the atmosphere, however, exposed to the action of water, especially with an increase of temperature, and under sufficient pressure, dead vegetation is converted into

Lignite or Coal. On this subject, Mr. Archibald Geikie says: "An example of this alteration was observed a few years ago in the Dorothea Mine, Clausthal. Some of the timber, in a long disused level, filled with slate-rubbish and saturated with mine-water from decomposing pyrites, was found to have a leathery consistence when wet, but on exposure to the air hardened to firm and ordinary brown Coal with the typical brown colour and external fibrous structure, and having the internal fracture of a black glossy pitch Coal. This change must have been produced within less than four centuries—the time since the levels were opened."

The vegetation forming or giving rise to Coal deposits, appears to have grown in wide shallow lagoons bordering the sea, or on low swamps and flood-plains near the mouths of rivers. In these situations dense masses of vegetation, differing considerably from that which grows in the same situations at the present time, clothed the moist soil. Over this the sea gradually found its way as the land subsided, burying the vegetation under thick layers of sand and mud. Removed from the atmosphere and under this enormous pressure, accompanied perhaps by subterranean heat, the vegetable matter was transformed by slow chemical changes (principally the removal of oxygen and hydrogen from the original woody tissue) into the mineral Coal, which in chemical composition, differs from wood mainly in having a smaller proportion of oxygen and hydrogen, and being richer in carbon. Subsequent elevation of the formerly depressed area would raise the vegetation, now converted into a Coal seam, above the level of the sea.

Mode of occurrence.—Coal occurs in layers or seams more or less horizontal in position, and ranging considerably in thickness. Below the seam is found almost invariably a layer of fire-clay, so largely used in the manufacture of certain kinds of pottery. The fire-clay was originally the soil in which grew the plants subsequently converted into Coal. It is frequently penetrated by roots, which, in some cases, can be traced back to the fossil trees occurring in the seams.

Sometimes the Coal-seams outcrop at the surface; but in most cases they are buried to a considerable depth. When this occurs, they are reached either by putting in drives or sinking shafts. The Coal is hewn out of the seams and hauled to the surface. A deposit of the mineral, worked in this way, is known as a Coal-mine.

The mineral Coal is found in most countries. Immense Coal-fields occur in England. Indeed, it is to the presence of these that she owes much of her prosperity. In New Zealand extensive deposits are found in the Auckland, Nelson, and Otago provinces, where mining is profitably carried on.

Uses.—Coal is one of the most valuable of all the minerals. It is used as fuel in the production of steam, and artificial heat for domestic purposes, and is also employed in smelting metals, baking clay, and the manufacture of gas.

Coal Gas.—Grind up some Coal and place it in the bowl of a tobacco pipe, as shown, being careful to cover the top of the bowl with clay so as to prevent the access of air. Heat the base of the bowl, and observe the yellow gas issuing from the end of the pipe. After a

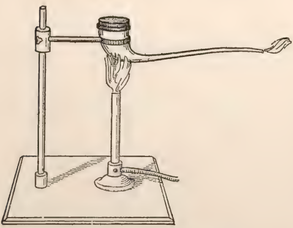


Fig. 148.—Pipe over gas flame.

time apply a lighted taper to the gas, and notice that it takes fire and burns as shown at A. The Coal, not having access to a sufficient supply of air, when heated does not burn, but is resolved into a number of products some of which—the gaseous—form the well-known Coal-Gas. It is this which burns at the end of the pipe-stem.

Manufacture of Coal-Gas.—Coal-Gas is prepared by what is known as the destructive distillation of Coal. This consists in heating the Coal in closed retorts out of contact with the air. The retorts, which are made of clay, are heated in a furnace, when the Coal is resolved into a variety of gaseous, liquid, and solid products which distil over and are collected. The volatile products obtained from Coal in this manner contain not only the mixture of gases known as Coal-Gas, but also a number of substances which must be removed before the gas can be used with safety and convenience for illuminating purposes. A detailed account of the process of manufacture will be found in any text-book of Chemistry.

During the process of manufacture a number of useful products are obtained; amongst these may be mentioned *Coal-Tar*, *Ammoniacal Liquor* from which most of the ammonia of commerce is derived, a number of brilliant *dyes*, and a very *sweet substance* used in the manufacture of certain kinds of confectionery.

The Gas itself is used chiefly for illuminating and heating purposes.

Lessons on Coal might with advantage lead up to others on Coal-mines and Coal-mining. These would be specially interesting within reach of Coal-mining areas, where visits could be paid to the mines and some of the operations seen in progress. It will obviously occur to teachers that it would not be a simple matter to arrange for a number of children to enter and explore a Coal-mine. Observations would to a large extent, if not entirely, be confined to surface operations. These, however, would prove full of interest and would help more than all available diagrams to make the subject real.

No attempt has been made to detail the operations carried on in Coal-mining, partly because lack of space forbids that the matter be further dealt with and partly for the reason that such descriptions can only be general and hence lose much of the interest which ought to surround them. A detailed description of the kind should have reference to some special mine with which the teacher and class are acquainted. If this cannot be done it will be sufficient (by the aid of diagrams and pictures) to lead pupils to follow a general account of mining operations.

III.—ROCK SALT.

As in the case of Coal, pupils will examine the specimens under review, and discover for themselves their physical properties. The same method of procedure may be adopted as that employed when dealing with Coal.

When pure the mineral is clear and colourless, but specimens of this kind are rare. An average piece of Rock-Salt is either reddish in colour from the presence of iron oxide, or tinged with green or blue showing the presence of copper. It is frequently mixed with impurities, usually clay or sand, which serve to modify its clearness still further. Its lustre is glassy, and its **transparency** varies considerably, the average being **translucent.** Though not so **brittle** as School Chalk and certain kinds of **Coal,** it is not difficult to break.

Chip off a piece of the specimen and observe the **fracture,** which in most cases is *conchoidal* or shell-like (see page). Break up the specimen still further and observe its **cleavage.** Notice the shape of the fragments, which generally take the form of cubes: *i.e,* its cleavage is *cubical.* Observe closely its **form** and make out whether this is *crystalline* or non-crystalline. If it shows cubical cleavage, its structure is crystalline.

Scratch the surface of the specimen with a file or knife-blade, and notice that it is easily cut into. Compare its **hardness** with Coal and other substances, and find out its place in the scale of hardness: *i.e.,* its hardness compared with that of other substances examined.

Its **taste** is easily determined—but pupils should be required to distinguish between the **saline** taste of Rock-Salt, the **sour** taste of a lemon, and the **bitter** taste of quinine, and the **acid** taste of vinegar.

Before determining its **specific gravity,** cover the surface of the fragment to be operated on with a thin coat of varnish to prevent solution. The varnish, should, of course, be allowed to dry before the mineral is immersed. The increase in volume owing to the presence of the varnish will be so small as not appreciably to affect the result of the experiment. For an account of the method of finding specific gravity see page 260.

Chemical Properties. Reduce a small portion of the specimen to powder, and heat this in a crucible over a hot flame. If the flame be hot enough, notice that the mineral does not burn, but gradually melts or fuses together into a mass which becomes compact and hard on cooling —it is, therefore, **fusible.**

Place some of the powdered mineral in a beaker containing cold water and stir well. Notice that it soon disappears—the water has dissolved it—it is, therefore,

soluble. Drop some more of the powdered mineral into the same vessel, and go on adding fresh supplies until the water ceases to dissolve it. Add a little more of the powdered substance so that the class can plainly see the deposit on the bottom of the vessel. Now place the beaker over the flame of a spirit-lamp or bunsen burner and heat gently—observe the gradual solution of the mineral. **Salt is more soluble in hot water than in cold.** Allow the solution to cool and notice the deposit of salt as the water cools. **Hot water will hold more salt in solution than cold water.**

After dissolving a sufficient quantity in cold water—filter the solution and obtain a **clear** liquid. Place this in a beaker over a bunsen burner, and by gradually driving off the water recover the dissolved mineral. Question pupils until they are quite clear as to what has taken place in each of these operations.

Origin. Rock Salt has been formed by the evaporation of very salt water in enclosed basins, a process now going on in many salt lakes, *e.g.*, Dead Sea, Great Salt Lake of Utah, Caspian Sea, Sea of Aral. From these lakes or inland seas there are no outlets, and the rivers flowing into them are constantly bringing down Salt in solution—hence the lake waters are becoming increasingly saline. In some of them the water-area is diminishing with the formation of lagoons round their shores. From these the water is being removed by evaporation, with the result that a constant deposit of Salt is taking place.

The Rock Salt of commerce has in ages past been formed in this way. The enclosed basins of Salt were gradually dried up, leaving deposits of the mineral behind. The areas containing these then subsided, and were covered up with material brought down by rivers, or spread out by the sea.

Occurrence. Owing to its solubility Rock Salt is not found near the surface in moist climates. It occurs in great quantities in the British Isles, Germany, Poland, and in many other countries. As giving some idea of the extent of some of the deposits, it may be mentioned that a mass of the mineral near Berlin has been bored through to a depth of 4,200 feet, whilst in Gallicia the accumulations have reached upwards of 4,600 feet. Rock-Salt has not been found in New Zealand.

How Obtained. The deposits of Salt are worked in much the same way as seams of Coal. Shafts are sunk, and the mineral after being hewn out is hauled to the surface. In some parts of the world the underground workings ar very extensive—in these live whole communities of people, who are content with an occasional visit to the surface.

Uses. Rock Salt is one of the most useful of mineral substances. From it is obtained much of the common Salt of commerce. The mineral after being taken from the mine is crushed and dissolved, when the earthy and insoluble portions settle to the bottom. The clear solution is then run off into pans, and the Salt recovered by evaporation.

From Rock-Salt also are obtained Hydrochloric Acid—so largely used in the manufacture of bleaching powder, and Carbonate of Soda, so useful for cooking and for cleansing purposes. Indirectly too, Soda used in the manufacture of Soap and Glass, is obtained from the same source.

We have seen that Salt is fusible, and, moreover, when the fused mass is allowed to cool, it consolidates and hardens. These properties enable it to be used as a **glaze** for common earthenware. The surface of plates and dishes in ordinary use are sometimes seen to be covered with small cracks, and in some places to be chipped. This has resulted from overheating. Salt fuses at a moderate temperature, which under certain conditions may readily be reached in the process of cooking. Should the dishes be raised to this temperature, the glaze will be injured.

All are familiar with the use the farmer makes of Rock Salt—how he places pieces in his fields and feed-boxes for cattle and horses to lick.

IV.—TABLE SALT.

Notice its white **colour** and glassy **lustre,** also that it is **opaque.** Let pupils feel it by rubbing it between their fingers, and ascertain that it is **hard, rough,** and made up of small grains, *i.e.*, **granular.** Call attention to Sand which is also made up of grains. Contrast the two substances, and make out that, whereas Sand is composed of little particles without any definite shape, the Salt-grains are all alike, the shape of each being cubical. These are, in fact, little Salt crystals each with six equal and similar faces. Salt is **crystalline.**

NOTE.—To see this properly a pocket lens will be required. Examine Sugar in the same way, and ascertain that it too is crystalline.

Test for its **taste,** and, as in the case of Rock Salt, require pupils to distinguish between salt, bitter, sour, and acid tastes.

Place some Salt in a beaker of water, and test for its **solubility**—both in cold water and in hot. See Rock Salt page 267.

What has become of the dissolved Salt? Let pupils taste the water. The salt is still in the tumbler, but its particles have been broken up so fine that we cannot see them. Evaporate the solution over a spirit-lamp or bunsen burner and show resulting deposit. Question pupils on this operation until they are thoroughly familiar with what has happened.

Heat a small quantity of Salt in a crucible over a hot flame, and find out that it is **fusible** (see lesson on Rock-Salt), but does not burn.

Leave some Salt exposed to the air in an open vessel—and observe that it has become quite moist. Lead pupils to see that the moisture must have come from the air—and hence to recognise the necessity of keeping Salt in a dry place and of covering up the vessels containing it. When making this test, the Salt to be operated on should be placed in a **damp** situation the evening before taking the lesson. In dry weather of course the amount of moisture in the air is so small as not appreciably to affect the exposed Salt.

Call attention to the vessels in which Salt is usually kept. Why are these made of wood and furnished with lids? Salt rapidly absorbs moisture, which is the great vehicle for the carriage of oxygen. The moist Salt coming in contact with a metal such as tin causes rapid oxidation; hence a tin vessel containing Salt soon becomes rusty and discoloured. Wood not only escapes oxidation, but is able to absorb some of the moisture from the Salt; the contents of the box are in this way kept clean and dry.

Where and how obtained. Salt is obtained from mines, from Salt or brine springs, and from sea-water.

When obtained from mines, the Rock Salt is brought to the surface, crushed and dissolved. The impurities are then removed by processes which are too complicated to be discussed here, and the pure Salt is recovered by evaporation.

In the case of brine springs the liquid is pumped into large flat metal pans. Under these fires are kindled—and the water is gradually driven off, leaving the Salt behind. This has to be freed from impurities before being used.

Sea-water contains about 3½ per cent. of solid matter in solution, the greater portion of which is Salt. In certain places this fact is made use of in obtaining the mineral. The water is led into shallow tanks, where it is allowed to remain until the heat of the sun brings about the necessary evaporation—or it is pumped into metal tanks and heated as described above. The Salt obtained from sea-water is brownish in colour and coarser and darker than common Salt—it is known as Bay Salt.

NOTE.—In sea-water there is a large amount of dissolved mineral matter in addition to Salt. This and other impurities have to be got rid of before the Salt is fit for use.

Uses. We are all familiar with the uses of Salt as food and in cooking. As food it is absolutely necessary —it supplies some of the mineral matter required by the body, and largely aids in the process of digestion. It flavours or gives a taste to much of what we eat—eggs, potatoes, butter, porridge, are insipid without the addition of Salt. In cooking, too, it is very largely used for the same reason.

Then, again, it preserves animal substances—meat, fish, butter, can all be made to keep for a considerable time without becoming tainted, by the addition of Salt.

For other uses see Rock Salt, page 269.

V.—SULPHUR.

Obtain, if possible, some specimens of native Sulphur, also one or two specimens of Roll-sulphur or Brimstone. The former will be needed, from time to time, for reference ; to the latter can be applied most of the tests referred to below.

Sulphur is a **yellow,** moderately **heavy** mineral. When native, it is **transparent** or **translucent** ; Roll-sulphur, in mass, is **opaque,** but in thin flakes or sheets is translucent. Its **lustre** is resinous, best observed in native specimens.

Chip a piece off one of the rolls and notice its **brittleness** and **uneven fracture** seen in the rough uneven surface left by the detached fragment. Compare with Coal. Native Sulphur has a **conchoidal** fracture, but, unless specimens are plentiful, this test may be omitted. Notice the absence of **cleavage.**

Test for **hardness** with a file or knife blade, as in previous cases, and compare with that of other minerals examined. It is well to keep a file or knife for this special purpose, so as to be able the better to compare results. As the tests are comparative, it is necessary that the testing instrument should not vary ; and, as all knife-blades and all files are not equally hard, the necessity of always using the *same* instrument becomes obvious.

Determine **specific gravity** as indicated on page 260 ; or, if this is not done, lead pupils to see that the mineral is heavier than water.

Let some of the pupils test for **taste** and **odour,** and ascertain that it is tasteless and unodorous when cold ; but when warmed, even slightly (*e.g.*, by being rubbed in the hands), it has a characteristic sulphurous odour.

Examine the specimen of native Sulphur, and ascertain that it is **crystalline.** Select some of the larger crystals, and make out, if possible, that they end in four-sided pyramids.

Find out, by experiment, that it is **insoluble** in water.

Hold a small piece of the roll in a flame of any kind, and notice that it readily burns — is very **inflammable.** Observe the dull blue flame, and the strong pungent fumes emitted.

Place a small piece of the mineral in a test tube, and heat gradually. Notice that it soon melts—is **fusible**—and that, in doing so, it changes its colour from yellow to dark red.

Pour out the melted sulphur into some cold water. Notice that it has become solid, but is soft and elastic. When this test is over, put the cake of melted sulphur away. Examine next day, and ascertain that it has reverted to a brittle and crystalline condition.

Uses. Sulphur is used in the manufacture of sulphuric acid, gunpowder, and lucifer matches; also for medicinal purposes. The fumes given off, when it is burning, are used for bleaching purposes.

Occurrence. Native Sulphur occurs most frequently in volcanic regions, considerable quantities being found in the Hot Lake district of this Colony, as well as at White Island in the Bay of Plenty. Some of these deposits are worked; but most of the Sulphuric Acid (the chief Sulphur product used in New Zealand) we require is imported from other countries.

The principal Sulphur mines are in Sicily; from these much of the Sulphur of commerce is obtained.

VI.—QUARTZ ($Si.O_2$).

In most of our mining districts, as well as in many others, Quartz is extremely plentiful—so that there should be no difficulty in obtaining suitable specimens for investigation. These should include some well defined crystals, as well as others showing the massive form of the mineral.

Notice the **colour** and general shape of the specimen under review—the colour will vary with the specimen. The crystalline form, when pure, is colourless; but it is more frequently coloured by impurities. Notice its glassy **lustre,** and determine whether it is **transparent, translucent,** or **opaque.** These properties will depend on the special specimen examined.

Ascertain that the mineral is not **brittle,** a considerable effort being required to break it; also that it is extremely **hard**—an average knife blade being readily scratched by it. Quartz is the hardest of all the commoner minerals, and can usually be identified by this property alone. In any scale of hardness prepared by the pupils, it wil probably stand at the top.

Chip a piece off one of the specimens which do not show crystalline form, and observe the conchoidal **fracture,** and entire absence of **cleavage.**

Notice that the mineral is crystalline, and make out the form of a few of the most perfect crystals — six-sided prisms, capped by six-sided pyramids. Determine, if possible, its specific gravity. Ascertain by trial that it is **tasteless, inodorous,** does not **burn,** is **insoluble** and **infusible.**

Occurrence. Quartz, which is pure Silica (oxide of silicon), occurs as an essential constituent of many rocks, *e.g.*, Granite and Rhyolite. It is also found filling up cracks, veins, and fissures in rocks. When the Quartz-filled fissure is large, the deposit is known as a **lode** or **reef.** All those living at or near gold-mining centres will be familiar with this form of the mineral. The white sand along the sea-beaches consists almost entirely of Quartz, the hard mineral being able to withstand the action of atmosphere and sea, under which the other rock-ingredients disappeared.

Uses. There are several varieties of Quartz called by different names: amongst the best known of these are **Rock Crystal,** or transparent Quartz, which is used in jewellery and for spectacle glasses; and **Amethyst,** a purple or violet-coloured transparent variety, largely used in jewellery.

VII.—CALCITE ($Ca.CO._3$).

One of the best known of the commoner minerals is Calcite, this being the name given to the purer forms of crystalline Limestone. It occurs in great quantities in all Limestone districts, both in masses shewing well-defined crystal form, and in pendant columns known as **stalactites.** It is also found in many places filling veins and crevices in rocks.

For purposes of examination, specimens containing characteristic crystals, as well as those showing crystalline structure, should be obtained, the latter to be made use of in applying those tests which require the specimens to be broken.

Observe the general shape of the specimen, its **colour,** which is usually white, and its **lustre,** varying from glassy to dull. Notice whether it is **transparent, translucent,** or **opaque** — this will depend on the specimen examined. Test for **hardness**, and notice with what comparative ease it is cut into with a knife; contrast with Quartz. Find its place on the scale of hardness already prepared.

Chip off a few fragments from one of the specimens, and observe that it is relatively **tough**, though much more **brittle** than Quartz. Examine the faces of the broken fragments, and notice that they are smooth and even, *i.e.*, the mineral splits up along **cleavage** planes and does not shew **fracture.** Contrast with Quartz, which shows fracture but not cleavage.

Break up a portion of the specimen still further, and carefully examine the fragments. Ascertain that all these, though varying in size, have the same shape, and if possible make out the form to be a solid bounded by six equal sides or faces, each of which is a rhombus.

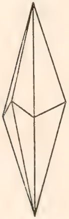


Fig. 149.—Calcite crystal.

Notice that the mineral is **crystalline,** and, if good specimens are available, make out the form of the crystal faces. This is not a difficult matter in good specimens. The crystals will be found to be pointed and six-sided, each side or face being a scalene triangle. Contrast with Quartz Crystal which ends in a six-sided pyramid, each face of which is an isosceles triangle.

Determine the **specific gravity** as in the case of other minerals. Test for **taste, odour, inflammability,** and **fusibility,** and ascertain that these are absent.

Pour a few drops of Hydrochloric Acid on one of the specimens. Notice the effervescence due to the liberation of Carbon-dioxide. Heat the acid in a test tube and again apply. Notice the increased violence of the re-action. Treat a piece of Carbonate of Soda in the same way, and explain that this test shows the presence of a Carbonate. Calcite is composed of Carbonate of Lime, and is identical in composition with Chalk—Limestone and Marble.

NOTE.—A Comparison and contrast between these two minerals (Quartz and Calcite) will naturally follow the investigations just concluded.

VIII.—IRON PYRITES (FE. S_2.)

Iron Pyrites or Iron Bisulphide is not an uncommon mineral in gold-mining districts, where it is usually known as mundic. With a little trouble good specimens can be obtained; specimens, that is, containing large crystals showing well defined crystal form.

Notice the general shape of the specimen; the bronze-yellow or brass-yellow **colour** of the mineral; its characteristic metallic **lustre,** and its absolute **opaqueness.** Ascertain that it is **tough** and **hard;** almost as hard as Quartz. Satisfy yourself that this is so by rubbing the minerals (Pyrites and Quartz) together.

Test for **fracture** and **cleavage**—the former is uneven, rarely conchoidal, and the latter is wanting.

Observe that it is **crystalline,** and determine the form of the crystals. These generally occur either as almost complete cubes, or as showing complete faces of cubes.

Determine its specific gravity as in the case of other minerals.

Ascertain that it is without taste or smell, that it will **not burn,** and is **infusible.**

Uses.—From it are obtained certain chemical products, amongst the most important of which is the Sulphuric Acid of commerce.

Occurrence.—Iron Pyrites occurs plentifully in both North and South Islands of New Zealand, especially in Quartz-mining districts. It is found in most other countries.

Note.—Though more suitable for country schools, or those within reach of mineral products, lessons on minerals need not, indeed should not, be omitted in any schools. It is not a difficult matter to collect specimens if one is really in earnest about it. The display may be small at first, but when once a beginning is made it will steadily grow, and gradually become a most useful school asset. Apart from the educative nature of these lessons, the knowledge acquired may prove of extreme value in a country like New Zealand, abounding as it does in mineral wealth, much of which is still untapped.

The lessons themselves may be begun in the lowest classes—where children can determine by observation some of the simpler properties of minerals—and gradually be expanded as the pupils become older and more intelligent.

The minerals dealt with have necessarily been few. They are however, forms easily procured, and the treatment it is hoped will indicate how the investigation of other minerals may be undertaken. Galena or Sulphide of Lead, Stibnite or Sulphide of Antimony, the Oxides of Iron, Ores of Copper, and other minerals are all procurable, and will furnish excellent subjects for further treatment.

A tabulated record of each investigation should be kept, since to this constant reference should be made during the progress of the lessons.

IX —METALS.

Minerals and Metals.—It is usual to include minerals and metals under the same heading—that is, to make no distinction between them. True, they both belong to the mineral kingdom ; but there is between them a very real and very obvious difference, and one, moreover, which children—especially those in the upper classes who have examined a few minerals in the way indicated, will readily appreciate and understand. None of the minerals we have dealt with are either **malleable** or **ductile**—all the metals possess these properties in a greater or less degree.

IRON.

Both the metal itself and specimens of Iron Ore should be available when dealing with these lessons.

Wrought Iron. Examine a piece of Wrought Iron. Observe the general shape and **colour** of the specimen. Scrape away the brown coating from the surface and ascertain that Iron is a **bright white** metal. Examine the polished surface of some iron articles, *e.g.*, knife-blade, scissors, fire-irons, and notice its bright shining **lustre.** Observe under similar conditions the lustre of other metals, and ascertain that they all have this shining appearance in a greater or less degree. Explain that this lustre is a special property of metals and is called **metallic.** Revert to the brown surface coating and elicit its name—**rust.** Draw attention to the conditions under which Iron rusts—viz., the presence of damp air—and explain the process—viz., the union of oxygen contained in the air or dissolved in water with the metal, forming an oxide of iron or rust. Educe that the metal is **opaque, tough** and **hard,** and find its scale of hardness; or compare it in this connection with other substances examined. Notice that it (Wrought Iron) is without **fracture, cleavage, crystalline** form, **taste, odour,** and that it does not burn.

Place a piece of Wrought Iron in a hot flame, and after allowing it to become heated quickly withdraw and hammer it on a suitable surface. Notice how soft it has become. Try the same operation with Iron which has not been heated. Iron becomes **soft** when heated, and can then be hammered out into thin sheets—it is **malleable.** Refer to iron wire and explain or educe that it can also be drawn out—Iron is **ductile.** Show pieces of Lead, Copper, Iron wire—also thin sheets of these metals, and lead pupils to recognise the same properties in each. Metals are **malleable** and **ductile.** Refer to some well-known minerals —Coal, Salt, Sulphur. Are these malleable and ductile? What then is the great distinction between a mineral and a metal? Educe from softening caused by moderate heat of gas flame or fire, that at greater heat they melt—Iron is **fusible.**

Wrought Iron is extremely tough and strong and is used in cases where these properties are essential. All kinds of farm tools—ploughs, harrows, etc.—are chiefly made of it; all kinds of smith-work are composed of it, as well as nails, screws, etc.

Cast Iron. Compare the hardness of Wrought and Cast Iron. Notice that the file readily bites into the former, but barely scratches the latter. Cast Iron is **harder than Wrought Iron.**

Take a piece of old saucepan and strike it sharply with a hammer; observe that it breaks into pieces with a rough uneven **fracture.** Test a piece of Wrought Iron in the same way. Notice that it does not break—Cast Iron is **brittle.**

Try to bend one of the larger fragments of the broken saucepan and ascertain that it remains **rigid.** Apply the same test to a piece of iron hooping or iron wire. Observe that it can be bent without breaking. Continue to bend it backwards and forwards until it breaks and notice that whereas the fragment of cast iron snapped clean through, the wire or hoop-iron leaves fibrous ends, shewing a kind of stringy composition. Cast Iron **is not flexible.**

Educe the uses of Cast Iron, which is much cheaper than Wrought Iron. It is used where rigidity is required and where toughness is not essential, e.g., for making grates, kitchen utensils, pipes used for drainage. What kind of Iron are horseshoes made of ? Why ?

Steel. Procure an old saw. Shew that it bends, and moreover that when the bending force is withdrawn it springs back to its former position. Test a knitting needle and a piece of the mainspring of a clock in the same way, and educe that whereas Wrought Iron is flexible, Steel is **elastic.** Test for **hardness** and ascertain that Steel is harder than either of the other kinds of Iron. Notice that there are degrees of hardness in Steel—clearly the file used in sharpening a saw is harder than the metal of the saw which is rasped away. Contrast the surface of a knife-blade or a pair of scissors with that of some article made of Cast or Wrought Iron, and observe that Steel takes a **better polish** than either of the other two.

Uses. Educe the uses of Steel. It is hard, elastic, and capable of being tempered to suit the purposes for which it is employed. All edge-tools or cutting instruments are made of Steel. It is also immensely strong, and hence is employed where strength and elasticity are essential, *e.g.*, for making ships, bridges, and wire ropes.

Manufacture of Cast Iron. Iron is made from Iron Ore, an earthy mineral found in large quantities in many countries. The ores employed are either **hæmatite** (one of the oxides of iron), or **clay-ironstone**, an impure argillaceous (clayey) Carbonate of Iron.

Roasting. The Ore is broken up, mixed with Coal and built into small heaps, which are kindled and allowed to smoulder for some time. During the process, which is known as **roasting,** the Ore loses about one-fourth of its weight.

Smelting. The roasted Ore is then mixed with about one-third of its weight of Quick-lime or Limestone, and almost its own weight of Coal, and emptied into a furnace. The Lime acts as a **flux**, causing the earthy impurities in the Ore to become liquid and separate from the Iron. Hot air is driven in through the burning mass until the heat in the lower part is so great that the contents become fluid. At intervals of half-an-hour or so fresh charges are introduced, and in this way the furnace is kept constantly full. As the mass becomes liquid, it runs down to the part of the furnace called the crucible—here the Iron proper, being heavier than the liquid slag, sinks to the bottom, and is drawn off at regular intervals. This process consists in exposing a small hole, and allowing the liquid Iron to flow out into specially prepared moulds. Each of the moulds is known as **pig**, and the Iron it contains is called **Pig Iron.** It is this which is re-melted and used in making **Cast Iron** articles.

Wrought Iron made from Pig Iron. During the process of smelting, the Pig Iron absorbed a portion of the Carbon of the fuel—it is this which makes the Iron so brittle; hence it is necessary to get rid of the Carbon in order to render the Iron malleable and ductile. With this object it is placed in a furnace constructed in such a way that the metal is melted without coming in contact with the fuel. This prevents it from absorbing any more Carbon and allows it to get rid of what it already contains. When melted it is well-stirred and hammered and finally formed into bars by being rolled out between steel rollers. It now possesses all the properties which make it so valuable—as malleability, ductility, tenacity, as also the power of being welded together at a red heat.

Steel made from Wrought Iron. The bars of Wrought Iron are placed in vessels filled with charcoal; these are closed and heated until a certain temperature is reached. This heat is maintained for about a week, when the whole mass is allowed to cool gradually. Usually, about three weeks are employed in the process; one to raise the mass to the required temperature; one to keep it at this temperature, and one to cool it.

Lead.

Pieces of the metal, as well as specimens of Lead Ore, **Galena** (Sulphide of Lead) should be available. This mineral occurs in many parts of New Zealand, and is not difficult to procure.

Observe the general shape of the specimen and its dull gray surface. Scrape off some of the surface and notice the bluish-gray tint of the metal, its true **colour**, and its bright metallic **lustre.** The gray film coating the surface is one of the Oxides of Lead, which has been formed by contact with the air. Ascertain that it is **opaque, tough,** and **flexible.** Notice its extreme **softness** compared with Iron. Lead is the softest of the common metals; it can be readily cut with a knife and may even be scratched with the finger-nail. Hammer a piece of the metal on a hard surface and notice its **malleability.** Procure some lead wire and educe that it is **ductile.** Test for its **tenacity** by hanging a small weight to the end of the wire, which is easily broken. Contrast this property with that possessed by Iron, Copper, and other metals, by attaching first the same and then heavier weights to wire made of these metals.

Determine its **specific gravity** and compare with that of Iron. Lead is the heaviest of all the common metals. Notice the absence of **taste** and the peculiar odour emitted when rubbed between the hands.

Heat some of the metal in an iron spoon or ladle and notice how easily it melts—It is **readily fusible.** Observe that when first melted it presents a bright glistening surface, but quickly becomes covered with a grayish-yellow powder-dross. This is an Oxide of Lead, and very poisonous—as are all the compounds of this substance, such as red-lead and white-lead (also Lead Oxides) both of which are used by painters in the preparation of their colours. Notice that, although readily fusible, it **does not burn.**

Make a clean cut through a leaden bullet, press the cut surfaces together with a slight twisting motion, and notice that they adhere with great tenacity.

Uses. The uses of Lead depend chiefly on its malleability, fusibility, flexibility, and its want of elasticity. It is used in sheet-form for roofing houses, for making gutters on houses, for covering the floors of bathrooms, and for lining cisterns. It can easily be bent or cast into any form and is used for making water and gas pipes, shot and bullets. When rolled out into thin sheets, it forms the lining for tea-chests.

Preparation. The metal is obtained either from the Sulphide or the Oxide Ore—the former, **Galena**, being the principal Ore of commercial importance.

The Ore Galena is first sorted, then crushed to a powder in a stamping mill, and washed to remove the earthy matters. After this it is roasted to get rid of the Sulphur, and then smelted. The smelting causes the remaining impurities to be removed, the volatile portions as gas, and the solid portions in the shape of slag. The heavier metal then sinks to the bottom of the furnace and is drawn off into iron pans.

NOTE.—Lessons on the metals can be begun in the lower classes, where a simple treatment will pave the way for a more detailed investigation in the upper standards. All the commoner metals, Zinc, Tin, Copper, can be treated in some such way as that detailed in this chapter. Lessons on the preoious metals will also prove of interest; but these are more suitable for schools within reach of gold-mining districts, where pupils are more or less conversant with the work of the mining community.

X.—ROCKS.

INTRODUCTION.—A rock, we have seen, is a mass of matter composed of one or more simple minerals. In point of fact most of the common rocks are made up of numerous crystalline or fragmentary particles which generally belong to several different kinds of minerals.

Classification. In attempting a classification of Rocks various plans may be adopted—we may arrange them according to their chemical composition, their general structure, or their mode of origin. A classification based on the two last considerations seems to offer greater chances of simplicity and altogether to be more suitable for our purpose.

If we examine a number of Rocks, we shall find for the most part that they can readily be divided into two main groups—viz. those whose particles are arranged in well-defined and regular layers, or strata, and those whose masses show no such arrangement. The former are known as **stratified** and the latter as **unstratified** Rocks. As stratification implies the agency of water, the former are sometimes spoken of as **aqueous** or sedimentary Rocks, and as, moreover, the particles of which they are composed have (in many cases) been derived from the disintegration of older rock masses, they are also known as **derivative** Rocks. Sandstone, mud-rock, or shale will furnish examples of sedimentary or derivative Rocks.

The unstratified Rocks are usually compact, crystalline, and of **igneous** origin—indeed the term unstratified is nearly coterminous with igneous.

Igneous Rocks are those which have been erupted from the heated interior of the earth, and include both **volcanic** rocks or those outflows of lava which have reached the surface, and **plutonic** or deep seated igneous masses which have cooled and consolidated at some distance from the surface. All these Rocks are compact, more or less crystalline, and unstratified.

Certain Rocks are met with which present a combination both of stratified and unstratified rocks, *i.e.* they possess crystalline structure in a greater or less degree, and though not arranged in regular layers, yet often show unmistakeable signs of stratification. They are in fact Rocks of whose sedimentary origin there can be little or no doubt; but whose structure has undergone a considerable amount of alteration since their original formation. These are called **metamorphic** Rocks of which Slate, Schist, and some Granites are examples.

Stratified or sedimentary Rocks must clearly have been derived from the disintegration of previously formed rock masses. Hence, in order to account for the formation of stratified Rocks, we must suppose the existence of masses from which their materials were derived. For this reason it is proposed to deal with **unstratified** or igneous Rocks first.

For our purpose then we may classify rocks as:

(1) Unstratified or igneous Rocks.

(2) Stratified or sedimentary Rocks, including all which have been laid down as mechanical or chemical deposits from water or air, and all which have resulted from the growth and decay of plants and animals.

(3) Metamorphic Rocks, or those which have undergone subsequent alteration within the crust of the earth, whereby their original characters have been changed.

In order thoroughly to appreciate even this brief classification, pupils should observe exposures of Rocks in the open country—such as are to be met with in pits, quarries, and cuttings of all kinds. It is only by examinations of this kind that they will be brought to realise the main characters which distinguish stratified from unstratified

Rocks. Cuttings showing stratification are within reach of most schools; attention should be drawn to these with special reference to the definite arrangement of the layers, and to the material of which the masses are composed. These will invariably be found to consist of particles of sand or mud—from which their sedimentary origin may be inferred. The presence of fossil shells will serve still further to strengthen the inference that they have been formed by the agency of water.

Examination of rocks. An investigation of Rocks may be undertaken in three ways. We can investigate their **macroscopic** characters, their **microscopic** characters, and their **chemical** composition. It is with the first of these only that we propose to deal; for necessary as all the other methods of examination are in throwing light on the structure and origin of rock masses, they are beyond what can be undertaken in our primary schools.

By macroscopic characters are meant certain external characters such as size, form, arrangement and general shape of component particles, which can be seen by the naked eye, or with the aid of a lens of low power.

Importance of a fresh fracture. One of the first things to be learnt in all examination of Rocks, is the way in which weathering conceals their true aspects. The nature of some of the operations whereby Rocks are acted on by the weather will be explained further. One has only to examine a fragment of Basalt showing surface weathering to appreciate the difference between the reddish earthy exterior and the hard compact core; hence the necessity of examining a fresh clean fracture. Still weathering under certain circumstances furnishes a valuable clue to the nature of certain rocks — the weathered surface of a hard crystalline Limestone, for instance, will sometimes show many projecting fragments of shells and other organisms.

The following are some of the headings under which an examination of rocks, such as we propose to undertake, may be carried out.

Colour.

General Structure.—*i.e.* whether crystalline or fragmental, whether close-grained or the reverse, whether particles are compactly or loosely held together, large or small, rounded or angular.

Hardness. **Specific Gravity.**
Cleavage. **Taste.**
Fracture. **Odour.**

XI.—UNSTRATIFIED OR IGNEOUS ROCKS.

The unstratified or igneous rocks are those which have been erupted from the heated interior of the earth, and have consolidated from a state of fusion. They include both **plutonic** rocks or those deep-seated masses which have cooled slowly and under great pressure, and **volcanic** rocks whose lava streams have reached the surface, where cooling has been relatively rapid. It is not proposed however to make any distinction between plutonic and volcanic rocks—but to include them both in the term **igneous.**

It is not within the scope of this work to do more than *briefly refer* to volcanic action; for the causes which lead to its development, and for a more detailed account of its manifestations, the reader must consult some work on dynamical geology.

The existence of a high temperature beneath the earth's crust has now been placed beyond all doubt by the evidence furnished by volcanoes, hot springs, and borings.

It is a remarkable fact verified by observations all over the world that below the limit of the influence of ordinary seasonal changes the temperature rises, as we proceed downwards, at the rate of about 1° Fahr. for every 50 or 60 feet of descent. This at a depth of 20 miles would give a temperature of 1760° Fahr. and at 50 miles one of 4600° Fahr., or higher than the fusing-point of platinum.

That rocks buried beneath the surface-crust must be at a high temperature there can be no doubt, though it does not follow that they are in a liquid or molten condition; for the pressure under which they exist is probably, if not certainly, sufficient to raise the point of fusion beyond even the high temperature attained.

From time to time, owing to earth movements and other causes, ways of communication are opened up between these underlying rocks and the surface. This has a twofold effect: it reduces the pressure and in some cases causes the superheated rock at once to become molten; and it furnishes a vent through which the molten material is forced to the surface.

GRANITE.

Granite is a crystalline compound of the minerals quartz, felspar, and mica. Typical specimens showing coarsely crystalline structure should be obtained—a face of one of these should be well polished—the others should show in places freshly fractured surfaces.

Observe the general **shape** and **colour** of the specimen—also the colour of the substances composing it. Notice that the particles of which it is made are firmly welded together and cannot be separated—that they form in fact a **compact** mass.

Examine the polished surface and make out as well as you can the form of the particles—notice that these are of definite shape and are bounded by flat surfaces—that they are in fact **crystals.** Observe, moreover, that the whole consists of certain well defined crystalline minerals and a mass of matter which appears to fill up the spaces between these. This too is crystalline, though the forms of the crystals cannot be seen—Granite is a wholly-**crystalline rock.**

Notice that it does not show **cleavage,** that it breaks with an uneven **fracture,** and is without **taste** or **odour.**

Determine its specific gravity.

Test for **hardness** and note the difficulty with which the knife-blade is made to scratch the surface. In this connection compare with other rocks.

Uses. Granite is highly prized for building purposes and for monumental work. Its hardness and other properties render it capable of taking a high polish, whilst the arrangement of its crystalline ingredients gives it, when polished, a very beautiful appearance.

Occurrence. Granite occurs in many countries—the Granite of Scotland, where extensive quarries are worked, has long been known to fame. It is found also in the South Island of New Zealand, in Nelson, Westland, and Otago; but so far it has not been met with *in situ* in the North Island.

NOTE.—Although Granite is commonly included amongst igneous rocks, there is little doubt that in many cases it has resulted from the metamorphism of stratified rocks. An account of the considerations which lead to this conclusion cannot be attempted here.

BASALTIC ROCKS.

Under this head is included a large and important series of volcanic rocks which consist essentially of Felspar, Augite, Olivine, and Magnetite, with other accessory minerals.

Basalt. Observe the general shape and colour of the specimen. Notice that, although it appears crystalline, the individual crystals cannot be made out as in Granite. Basalt may be called a **crystalline** rock, though it differs from Granite in not being wholly-crystalline; this difference in structure, however, cannot be seen without the aid of the microscope.

The **texture** of basalt varies with the specimen; notice whether this is close-grained and compact, or vesicular *i.e.* containing small cavities in greater or less abundance. Many volcanic rocks show this structure — at the time of their eruption they were saturated with steam, and the expansion of the imprisoned vapour has subsequently developed internal cavities.

Test for its **hardness** and compare with Granite. Notice that the typical Basalt is a hard close-grained compact rock, tough and durable — qualities which render it valuable as building-stone and as road-metal.

Observe its want of definite cleavage, its uneven fracture and the absence of taste and odour. Ascertain its specific gravity and compare with other rocks.

Basalt occurs in several parts of New Zealand in some places forming rock-masses of considerable extent. It is a volcanic rock and has been poured out at the surface in the form of lava flows. These frequently assume what is known as a columnar structure—that is the mass splits into slabs or columns, each having a varying number of sides. An exposure where this has occurred shows a mass of closely fitting columns, in some cases arranged with wonderful regularity.

Uses. Basalt is used as a building stone and as road metal, its hardness, durability, and property of resisting the attacks of the atmosphere and the weather, rendering it valuable for these purposes.

The soil resulting from the weathering of Basalt is usually fertile and easily worked.

Andesite.

Under this term are included volcanic rocks composed of Felspar, Augite, and other minerals. The rock itself differs from Basalt mainly in the absence of Olivine. Some varieties of Andesite show large well defined crystals of Augite or Hornblende and, according as one or other of these minerals predominates, are known as Augite-andesite or Hornblende-andesite.

The rock itself is very like Basalt in appearance; indeed it requires some expert knowledge to distinguish between average hand specimens. Those kinds which show well-marked Augite or Hornblende crystals are easily identified.

Examine the specimens, as in the case of Basalt, and ascertain that Andesite is a **compact close-grained** rock, relatively **free** from vesicles, **crystalline,** and **dense,** that it is **tough** and **hard,** breaks with an uneven **fracture,** and is without **taste** or **odour.**

Certain kinds of Andesite, when beginning to weather, have a tendency to cleave along definite lines—the rock tending to break up into rectangular masses of varying size. This property is rarely met with in fresh unweathered exposures—the typical Andesite showing no cleavage.

Determine its specific gravity and compare with other rocks. Andesite occurs in most countries, and is amongst the best known of New Zealand volcanic rocks—being found throughout both islands. It is used for building purposes and for road metal.

Rhyolite.

Rhyolite is a volcanic rock almost identical in composition with Granite—that is, its essential constituents are

Quartz, Felspar, and Mica. It differs from Granite in not being altogether crystalline. In Granite the whole of the minerals composing the rock are in a crystalline form *i.e.* the rock is **wholly-crystalline** ; in Rhyolite a number of crystalline minerals are imbedded in a non-crystalline or vitreous ground-mass.

Observe the light grey **colour** of the specimen; notice that it is **compact, dense,** and **crystalline.** Ascertain whether in structure it shows a number of small spherical masses (having a radiating structure when broken across) or well defined bands of varying colour — both the "spherulitic" and "banded" structures are characteristic of Rhyolite.

Test for its hardness and determine its **specific gravity** ; ascertain that it **fractures** with an uneven surface and that it is without **cleavage, taste,** or **odour.**

NOTE.—It might be well, before dealing with unstratified rocks, to give some lessons on volcanic action and volcanoes. This would be specially interesting in a district within reach of volcanic outcrops, which should be visited and the massive unstratified form of the rocks made clear. It is not recommended that the difference between plutonic and volcanic rocks should be taught—it is best to call them all **igneous** or eruptive rocks. Their examination should be directed towards bringing out common characters—viz. that they are all close grained, compact, hard, without stratification, and crystalline.

Any classification of igneous rocks must under any circumstances be a matter of some difficulty, so that each teacher will have to decide how far it is desirable to go in this direction — much will depend on the school surroundings, the tastes of the teacher, and the intelligence of the pupils. Whatever is attempted should have simple beginnings, and in development should avoid as far as possible involved and complicated details.

It is needless to say that there will probably be other volcanic rocks within reach of the school, besides those described. These should be collected, examined, and named. A short description of the rock with its name and place of occurrence (locality) should be written on a card and placed beside each specimen in the museum.

In localities where no volcanic rocks are available, specimens should be obtained from other places.

XII.—STRATIFIED OR SEDIMENTARY ROCKS.

SANDSTONE.

Sandstone is a rock composed of consolidated sand, the particles of which are usually quartz. In ordinary sea-sand the grains are similar in composition, shape, and appearance to those found in Sandstone—*i.e.*, they are grains of Quartz. In the original rock, from whose disintegration the sand has been derived, the hardest and most durable mineral was Quartz—hence it was able to resist the attacks of erosive agencies, whilst the other more perishable minerals were carried away in solution or in suspension as fine mud.

Sandstones vary greatly as to their degree of consolidation, from a mere sand-rock, which is just compact enough to stand with a vertical face, to a dense compact gritstone sufficiently hard to be used for the grindstones of flour mills. The size of the grains also varies, from the most minute particles of quartz to grains as large as peas, the rock then commencing to pass into a conglomerate. In colour, too, a considerable difference is noticeable. This arises, not so much from the colour of the Quartz, which is commonly white, as from ingredients in the cementing material, which holds the grains together.

For purposes of examination, a number of specimens should be obtained. These should range, in texture, from fine to coarse, should vary in hardness from soft to indurated, and should show, so far as hand specimens can, distinct evidences of stratification.

Notice the shape and general colour of the specimens. Select a moderately soft coarse-grained specimen, and scrape away some of it with a knife. Examine the fragments carefully, and note that they consist of small hard angular or sub-angular **grains**. Compare with sand obtained from the sea-shore, or a river-bed, and ascertain that the mass is composed of **sand-grains firmly cemented together**. Refer again to colour—the sand-grains from the sea-beach are white, the **rock** is coloured red, brown, yellow, green—as the case may be—explain that the colouring matter lies in the cement.

Contrast with some of the igneous rocks *e.g.* Granite or Basalt — notice that the latter is compact, dense, and consists of minerals—some of which show the form of crystals, all of which are imbedded in a hard matrix — and none of which can be rasped away from the rock without being injured—Sandstone, on the other hand, is made up of grains, of fairly uniform size and irregular shape, which can be detached with relative ease, and for the most part are composed of the same mineral. Igneous rocks are crystalline ; typical Sandstones are non-**crystalline** and **fragmental** *i.e.* are composed of fragments which once belonged to other rocks.

Cut into several of the specimens and notice the difference in **texture** or size of the particles, and in hardness. Educe that the latter is mainly due to the cementing material. Notice in some of the specimens the well marked **stratification.**

Test for **brittleness** and notice that this differs with the specimen—also for cleavage, a property which is well marked in some varieties. Notice the uneven **fracture** and in most cases the absence of **taste** and **odour.**

Origin. Place a few pieces of hard igneous rock in a bag and shake up for a few minutes; open the bag and ascertain that particles have been broken off. Educe that rocks tumble into the sea or into rivers and are rubbed against each other until they are ground to pieces—that the softer minerals are either dissolved or reduced to mud and carried away—and that the harder minerals alone remain. Refer to lesson on Quartz, note that it is the hardest of all the minerals examined, and explain that it is one of the commonest rock-forming minerals, and hence that it is not surprising to find it in such quantities in sea and river-sand.

Mix up some gravel, fine and coarse sand; empty this into a wide jar containing water and, after shaking up the contents, allow the whole to settle. Notice that the solid particles have arranged themselves in definite layers, the coarsest and heaviest at the bottom and the finest and lightest on the top. Explain that rivers and currents carry the sand and spread it over the sea-floor where it settles down in definite layers, and where partly by the pressure of the deposit itself and partly owing to the cementing material which gradually finds its way into the mass and unites the grains, the whole is cemented into rock. Explain the meaning of the term **sedimentary**. Explain further that the crust of the earth is undergoing slow and continuous movement, that some parts are being depressed or lowered, and others are being upraised; that the layers of Sandstone laid down on the sea-floor in ages past have been elevated above the sea level until they have become dry land. Recapitulate reasons for supposing Sandstone to be a rock of aqueous origin.

(*a*) Composed of grains similar in all respects to sea or river-sand.

(*b*) Particles arranged in different layers *i.e.* rock is stratified.

(*c*) Rock frequently contains marine organisms.

Uses. The uses to which Sandstone is put depends largely on the hardness and texture of the rock itself. Some varieties—notably the Oamaru Sandstone—form excellent building material; others again, the harder varieties, are used for grinding purposes, and in many districts in New Zealand are employed as road metal.

SHALE.

The term Shale is here applied to the finer grained fragmental rocks, and is used to include Mudstones and Clay-rocks as well as Shale proper.

A Shale, then, we may define as a fine, more or less sandy or clayey rock, whether laminated or not, of varying hardness.

The specimens for examination should include several varieties of Shale, both hard and soft, with one or two pieces showing lamination.

Notice the general shape of the specimen and its **colour, feel, taste,** and **odour.**

Select a soft specimen, scrape away some of the surface with a knife, collect and carefully examine the material so obtained. Empty some of it into a jar of clear water; shake up and notice the turbidity of the liquid. Place some more of the material in a beaker, and having poured on just sufficient water to moisten it, work the whole up into a thin paste. Compare with the muddy deposits left on a sea-beach, or river-bed, or on the bottom of pools along the road. Educe that the material being examined is fine **clay** or **mud,** and that the rock is a clay or mud rock. Supply the name **shale,** and compare and contrast the rock with Sandstone. Both are formed by agency of water; both are stratified and both consist of fine particles cemented together. Sandstone, as its name implies, is composed of grains of sand; Shale, on the other hand, is made of fine clay or mud.

Examine a number of the other specimens and compare them as to **hardness, texture, fracture,** and **cleavage.**

Notice the ease with which the laminated specimens split into thin leaves along lines of deposit. *Note.*—Shale proper always possesses this laminated and fissile structure.

As in the case of Sandstones, educe that all these rocks are of **aqueous** origin—are in fact **sedimentary** rocks.

Refer to material shaken up in glass jar, most of which will be still suspended in the water. Draw attention to length of time required for fine material to settle—refer to what happened when sand, fine and coarse, and gravel were shaken up in jar. Which came to rest first on bottom of jar? Which remained longest in water—and why?

Educe that rivers or currents carrying or moving sediment along will drop the heavier grains first—*i.e.*, near the shore, and that the finer and lighter particles, taking longer to settle, will be carried far from land before coming to rest. In this way lead pupils to see that Sandstone was laid down in shallow water, relatively near the land, whereas Shale or mud rocks were deposited in deep water.

NOTE.—Shales present almost endless variety of texture and composition, passing on the one hand into Clays, or where much hardened into Slates, and on the other hand into Sandstones.

XIII.—GRAVEL AND SHINGLE.

Gravel is the name given to water-worn stones, ranging in bulk from the size of a small pea to that of a walnut, whilst the term **shingle** is applied to coarser debris ranging up to blocks as big as a man's head or larger.

A number of specimens taken at random from a gravel pit, a sea-beach, or a river bed will usually include **different kinds of rock.**

Notice the smooth rounded surface of each stone. Educe that pieces of rock break off and tumble into the sea or river beds—that these are rolled over and ground together by the action of the waves or river currents, that the angular projections are first removed, and that the grinding process continues until the stone is rounded and smooth.

Examine a few of the separate stones, and notice that they are not all composed of the same material.

Educe where Gravel is most likely to be found. Why on sea-beach or in river-bed ? Why are the stones in the lower courses of rivers more rounded and smooth than those near the source ?

CONGLOMERATE.

Conglomerate is a mass of consolidated Gravel or Shingle, the pebbles being rounded or waterworn, and set in a paste or cementing matrix which binds them together into a hard mass. The pebbles may consist of any kind of hard rock or mineral, which is able to resist the grinding process to which it is exposed. A special name may be given according to the nature of the pebbles—when these consist chiefly of Quartz, the rock is called a Quartz-conglomerate; when they are Limestone, it is a Limestone-conglomerate, and so on. The matrix binding the pebbles also varies in composition—sometimes it is merely sand, and the rock seems to have been consolidated simply by pressure. In other cases it consists of cement which has set so hard that a blow produces a clean fracture through both matrix and pebbles. The cementing material may be Silicious, Calcareous, Clayey or Ferruginous (abounding in Iron).

Specimens of Conglomerate are not difficult to obtain in some localities—though typical varieties may not be so easily procured.

Examine the specimens available and ascertain that they consist of bits of rock, often of different colour, shape and hardness (*i.e.*, the pebbles themselves belong to different rocks) imbedded or set in a cement or matrix. The whole looks like a plum-pudding with stones appearing through it instead of plums—hence the popular name, **pudding-stone.** Scrape away some of the matrix and detach a few of the pebbles. Notice that they are rounded and smooth. Educe that they are waterworn, and have been formed along a sea-shore or in a river-bed.

Examine the matrix, *i.e.*, remove some of this with a knife or hammer, and break it up either by rubbing it between the fingers or by gentle blows of a hammer, using no more force than is necessary to separate the particles. Place the powdered material in a glass jar containing water, shake up, and allow the jar to stand for some time until the contents begin to settle. If the matrix be composed entirely of sand, the particles will quickly drop to the bottom ; if of sand and mud, the sand will settle in a layer and the mud will remain suspended for a relatively long time. Determine in this way the composition of the matrix.

Origin of Conglomerate. Educe that the pebbles came from a sea-beach or river-bed—referring to any deposit of Gravel or Shingle in the neighbourhood. Refer to the way Concrete is made, viz., by mixing pebbles with slaked lime or cement and water, and leaving the mass to set. Educe that Nature in a similar way binds the pebbles and sand together partly by pressure and partly by causing some cementing material to find its way into the mass.

Refer again to the localities where Gravel and Shingle are being formed. Are these likely to be found far from the sea-shore? Why not? A strong current is required to force them along. The rivers sweeping down into the sea cannot carry them far, for the current is checked on reaching the sea. The currents along the coasts, too, are unable to move them to any great distance. Educe then that Conglomerate has been formed in a river-bed or along a coast line, not far from land. Contrast with what has already been learnt about the origin of Sandstone and Shale.

Note.—When the fragments are angular, the rock is called a **breccia.**

NOTE.—There will be little or no difficulty in enabling pupils to recognise the characteristics of some of the commoner of the sedimentary rocks, *e.g.*, their stratification and fragmental origin.

Stratification to be realised should be seen in the field, so that it will be necessary to direct the attention of pupils to some typical exposures in the district if time cannot be found for taking the whole class to examine these *in situ.* The latter, of course, is the more preferable plan, and should be adopted when possible.

The two kinds of rock, aqueous and igneous, should be carefully contrasted and their differences noted—igneous, massive, and crystalline ; aqueous, fragmentary, and non-crystalline.

Some time should be devoted to determining the aqueous origin of certain rocks. If fossil-bearing strata occur in the neighbourhood, a visit to these should certainly be made—not with the object of collecting fossils, though such work has its use—but for the purpose of bringing children into contact with perhaps the most convincing proof of the conditions under which the rocks were formed. To those who have already been through a course of lessons on molluscs, and have begun to identify forms by their shape, appearance, and markings, a fossil bed will prove of great interest, especially if it be of recent age. Under certain conditions pupils might be encouraged to collect and, aided by the teacher, to identify, care being taken to note the kind of rock in which the fossils occur. A collection thus obtained would be of great use in any school and would serve to bring home to children as perhaps nothing else would that much of the solid crust of the earth was at one time buried beneath the waters of the ocean. The difficulty of realising this fact would to a large extent be removed if the child actually discovered for himself some of the evidence on which it rests.

It is not recommended that the naming of the numerous specimens be made a matter of special attention—and this also applies to fossils—though names should be given where possible, as they provide an easy and convenient means of referring to what has already been done. The primary object should be to examine and describe the rocks, not to find names for them. Collecting as an *aid* to Rock-study is of such importance as to become almost a necessity—but collecting as a *substitute* for Rock-study can only result in very little real good being done.

It is hardly necessary to add that the rocks to be studied first are those in the immediate neighbourhood of the school. These are the ones which should receive most attention. Specimens obtained from a distance will prove a valuable aid in expanding and reinforcing what has already been done—that is, their investigation should follow that of local specimens.

It should be borne in mind from the outset that the work suggested here is not Geology, but is to be undertaken with the object of questioning Nature, observing her methods and answers, and of generally encouraging a spirit of enquiry.

XIV.—LIMESTONE.

Limestone may be defined as a mass of Calcium Carbonate, sometimes nearly pure, when it is soluble in Hydrochloric Acid, and sometimes loaded with Sand, Clay, or other impurities. Few rocks vary more in texture or composition—it may be hard and close-grained showing conchoidal fracture, or a crystalline rock composed of crystals of Calcite—or a dull, earthy, friable mass. In colour, too, it varies considerably—the most common shades being blue-gray passing to white.

A great deal of Limestone occurs in New Zealand, so that it should not be a difficult matter to secure plenty of suitable specimens. From these a few typical ones should be selected for investigation. The non-crystalline varieties are best to begin on, though the harder crystalline rocks should certainly be examined.

Note the **colour** of the specimens, and compare with calcite. Educe the characteristic white appearance they all present—test for **hardness,** and if several specimens are available for examination, determine which variety is hardest. Taking one of the specimens, observe its **texture** —make out that it is either crystalline or composed of small particles more or less firmly held together.

Test for **cleavage** and **fracture.** The former will most probably be absent—the latter may be uneven, splintery, or conchoidal. Notice that it is much more **brittle** than most of the volcanic rocks dealt with—more easily broken, and more easily reduced to powder. Examine carefully both the outside surface of the specimens and the material scraped off with a knife, and notice if any small shells or other organisms are to be seen. These, though they cannot be seen in the mass itself, are often visible on the weathered surface. By selecting a few suitable specimens, the organic origin of the rock can be made clear.

Test for **taste** and **odour**; and determine **specific gravity.** Pour a few drops of dilute Hydrochloric Acid on a clean surface and observe the effervescence; heat the acid and again apply—notice the increased violence of the re-action. Powder up a small quantity of the rock and drop into a test tube, cover with acid—notice (if the rock be pure) that the whole of the material will disappear. Limestone **effervesces when acid is poured on it** —and is **soluble in acid.** Pure Limestone is composed of Carbonate of Lime—*i.e.*, of Carbon-dioxide and Lime chemically united. When acid is applied, the Carbon-dioxide is liberated; hence the effervescence.

Test for its solubility in water, and ascertain that it is practically insoluble. Heat strongly some of the rock in an iron pipe. When cool, place the pieces on a tin dish, and pour some water over them. Observe that the whole becomes very hot, that steam rises from it, and if the proper quantity of water be used, that the rock crumbles to powder. The heat applied to the rock drove off the Carbon-dioxide, and left the Lime—commonly known as **quicklime.** The water subsequently used was absorbed by the quicklime with the result that the substance became **slaked lime.**

Uses. Limestone is obtained in many parts of New Zealand, where immense deposits of it occur. The rock is burnt in kilns and coverted into Lime, which is used in making mortar or as a dressing for soils. A soft kind of the rock known as **Chalk,** is used for writing on the blackboard—and for marking wood. When finely-powdered the same material is employed in making tooth-powder, or is known as **Whiting**; by mixing it with oil it forms putty.

A granular Limestone, known as **Marble,** is used in buildings and for making monuments, table-tops, mantle-pieces, ornaments, etc., etc.

The only use made of Limestone in New Zealand is to convert it into Lime, which is employed in making mortar and as a dressing for soils. In several Limestone formations in New Zealand good samples of granular marble occur. These, however, are not worked.

Stalactites and Stalagmites. In almost every Limestone district, certainly in every district where there are Limestone caves, these formations occur.

Water containing an excess of Carbon-dioxide in solution possesses the power of dissolving Limestone. The Carbon-dioxide necessary to convert it into a solvent is acquired by the water in its passage through the soil, so that when it reaches the roof of the cave, it contains Carbonate of Lime in solution. As each drop gathers on the roof and begins to evaporate and lose Carbon-dioxide, the excess of Carbonate of Lime which it can no longer retain is deposited round its edges as a ring. Drop succeeding drop, the ring gradually grows into a long hanging tube, called a **stalactite**—usually having a small aperture down the centre—which, by degrees becoming longer and thicker, may reach the floor, and develop into a massive pillar.

The deposits on the floors of caves formed by water carrying Carbonate of Lime in solution, and depositing it under similar conditions, are known as **stalagmites**.

Origin. Although included under the heading of sedimentary or aqueous rocks, Limestone is a rock of organic origin—that is, it has been formed largely, in some cases entirely, from the remains of minute organisms which have gradually accumulated on the sea-floor. Many marine and fresh-water animals (shell-fish and other organisms) possess a covering or skeleton composed mainly of Carbonate of Lime, and coral reefs consist of the same material. Deposits of organisms, from various sources, took place in ages past on the sea bottom—subsequent elevation raised the deposits, converting them into dry land. Similar deposits are now taking place in many of the seas—a study of which has thrown much light on the formation and growth of limestone.

The rock may also be formed by a chemical deposit from calcareous springs—such deposits, however, are much less common and less extensive than those of organic origin. Originally formed deposits frequently lose their fragmental, and acquire instead a crystalline structure.

NOTE.—The organisms which compose most varieties of Limestone live in deep water—hence Limestone has been formed further from land than either Sandstone or Shale—*i.e.*, in clear water.

XV.—METAMORPHIC ROCKS.

Metamorphic rocks have been described as those which have undergone subsequent alteration within the crust of the earth whereby their original characters have been changed. It is not proposed here to attempt any explanation of metamorphism ; for this the reader is referred to works on dynamical geology.

Many rocks exhibit a peculiar **fissile** structure which causes them to split along planes—more or less oblique to their planes of bedding ; others appear to consist of a mass of thin leaves, *i.e.*, show a **foliated** structure. Moreover, it sometimes happens that different kinds of foliated rocks are superimposed on each other in such a way as to suggest, if not indicate, stratification. Yet such masses are frequently crystalline, and in other respects differ entirely from what are known as stratified rocks.

Though considerable differences of opinion exist as to the origin of these rocks, most geologists are agreed that they were originally sedimentary deposits, and have been metamorphosed or changed to their present condition through the operation of mechanical movement, combined with the influence of heat, and heated water or vapour.

Two kinds of metamorphism are recognised, one known as **local metamorphism** when the change has been effected within a limited area only round some eruptive mass, and the other as **regional metamorphism** when the change has taken place over a wide area.

As examples of the former it may be mentioned that in certain places intrusive sheets of igneous rocks have baked the clays through which they pass into **porcellanite** —a substance very like the material of a burnt brick ; also that other intrusive sheets forced into masses of limestone have converted the limestone into **marble.** That is, local metamorphism is mainly due to the presence of heated masses of igneous rock.

But foliated crystalline rocks occur over such vast areas that their metamorphism cannot be explained by the action of intrusive igneous masses. Indeed they are frequently unconnected with any igneous rocks whatever. Most of their rocks exhibit foliation or the arrangement referred to previously—moreover the crystals are arranged in definite planes so as to give a grain to the rocks. The opinion is that these rocks, originally sedimentary deposits, were carried to a considerable depth from the surface, where partly by the internal heat of the earth and the heat caused by friction between the particles as the masses were being compressed, (in the presence of water), and partly by the pressure and folding to which they were subjected, their entire characters were changed. Such masses exhibit regional metamorphism, well seen in parts of Otago where large areas of **schistose** or **foliated** rocks occur.

Amongst the best known metamorphic rocks are Granite, Gneiss, Schist rocks, and Slate.

Granite we have included amongst the igneous rocks, and have already described. Its origin is not always very clear. Sometimes it is undoubtedly an igneous rock, but its mode of occurrence at other times leaves little room for doubt that it is an altered sedimentary deposit—in other words a **metamorphic** rock.

Gneiss.

This rock consists practically of the same constituents as Granite, from which it differs mainly in the foliated arrangement of the minerals.

Note its crystalline structure and the banded appearance of the mass—the light coloured **felspars** and **quartz** and the dark folia of **mica**. Determine whether the lighter bands are composed entirely of Quartz or of Felspar, or are made up of a mixture of these two minerals. This in some specimens can be readily done by testing with a knife, the Quartz being harder than the Felspars. Note the lenticular nature of the bands, the way in which they thin out and disappear, reappearing again on the same or on a different plane. In some rocks the foliation is so massive that it can be seen only in the field.

Test for cleavage and notice the tendency to split along definite lines, *i.e.*, in the direction taken by the bands.

Test for hardness and determine specific gravity. Compare and contrast with Granite.

Though Granite is found in many parts of the South Island of New Zealand, typical outcrops of Gneiss do not occur.

MICA-SCHIST.

The schists are crystalline rocks whose minerals are arranged in fine folia or layers. In composition they vary considerably, and are named after some characteristic mineral they contain; the word Schist being employed as a suffix. Thus we have **Mica-Schist, Hornblende-Schist, Chlorite-Schist.**

Mica-Schist, which is probably the commonest of those mentioned, may be taken as a type. It consists of a mixture of Quartz and Mica in alternating layers; the relative proportions of these minerals often vary in different parts of the same rock.

Note the colour of the specimen, which alters with the hue of the Mica from light to dark greenish-grey; its smooth silvery surface, and the thin lenticular wavy layers or laminae, of which it is composed. Observe whether the laminae lie flat, one on the top of the other, or are thrown into folds—**contorted.**

Notice the ease with which it **cleaves**, and the direction of the cleavage planes, *viz.*, between the folia. Rocks which cleave in this way are said to be **fissile**, a structure which is characteristic of all Schists. Observe the glistening Mica on the freshly exposed cleaved surface. As the Mica lies in thin plates between the layers, the Quartz is not readily seen. Take a thin piece of the rock, break it across, and observe the Quartz-layers in the cross fracture.

Test for hardness, and notice that the rock can be scratched with the knife-blade. Why is this ? What is the chief mineral exposed, and hence what mineral is the knife cutting or rasping away ?

Determine the specific gravity, and compare with other rocks.

Compare and contrast with Gneiss, and notice that it differs from this rock mainly in the thinness of the layers, in the more regular arrangement of the minerals, and in its fissile structure.

The Schists in this country are found in the Otago province, where they cover large areas ; also along the flanks of the Southern Alps in Westland, and in various localities in Nelson and Marlborough. They are unknown in the North Island.

SLATE.

The term Slate is usually applied to an argillaceous not obviously crystalline rock, in which cleavage has been well developed, so that the rock splits into thin parallel layers. The term, however, is not confined to rocks of this class—the well-known **maitai** formation, which outcrops at intervals from the northern portion of Otago to the Bay of Islands, is classified as a Slate rock, although the fissile structure of the typical Slate is entirely absent.

It is, in fact, an indurated argillaceous sandstone, varying considerably in texture. For purposes of investigation, it is better to obtain typical Slate-rocks—*i.e.*, those showing well-defined fissile structure. Observe the bluish-gray colour of the specimen and its dull surface. Slates have this dull appearance, unless highly polished or wet. Draw attention to the term **slate colour.**

Take a piece of Slate and a piece of Shale of nearly equal weight: carefully weigh these, and place them in a vessel of water at the beginning of the lesson.

Notice the readiness with which the slate-mass splits into parallel layers. Observe the thickness of these, and make out that the rock is composed of a great many very thin folia or leaves between which run the planes of cleavage —that in fact it is **fissile.**

Break the rock across, *i.e.*, at right angles to the planes of cleavage, and notice the difficulty of doing so, as also the projecting edges of the exposed folia.

Test for hardness and determine by comparing with other rocks that Slate is relatively soft. Discover, by trial, that the hardness often varies with the specimens, some kinds being much softer than others. Which is harder—the school slate or the pencil which is used to write on it? Why?

Grind down a piece of the rock and show that, like dry clay, it can be reduced to a fine powder. Compare this with the powder obtained by a similar treatment of Shale. Mix the powdered Slate with a little water and notice that it forms a kind of clay. Both Slate and Shale are of sedimentary origin, and both were originally composed of the same material. The alteration in the composition and arrangement of the mineral contents, whereby Shale has been converted into Slate, is the result of **metamorphism.**

Obtain, if possible, a vessel made of Slate, or hollow out a small cavity in one of the specimens, fill with water and notice that the liquid does not pass through. Take out the pieces of Shale and Slate previously immersed in water, and, after wiping the moisture from the surface, carefully weigh and compare with the weights already taken. Notice that both have increased in weight—but that the Shale has increased in a greater degree than the Slate. As the additional weight is due to the water absorbed, a relatively small amount of water must have passed into the Slate.

NOTE.—The softer kinds of Slate absorb a good deal of water; it is the harder kinds that are impermeable.

Determine the specific gravity and compare with other rocks.

Uses. Its lightness, the readiness with which it can be split into thin pieces, and its power of keeping water from passing through, make Slate valuable as a roofing material, It is sometimes used to put between the bricks at the lower parts of houses, to prevent the moisture which is always rising from the ground passing up into the bricks. It is also used for school slates, baths, water cisterns, shelves, chimney-pieces, and for paving streets.

Where found. Typical fissile Slate has not been found in New Zealand. It occurs in great abundance in Wales, also in Scotland and Ireland. The Welsh Slate quarries have long been famous, and still supply a large quantity of the material used in the British Possessions. The rock is hewn out of the quarry, and either split or sawn into the shapes required.

NOTE.—The Metamorphic rocks will prove of most interest in a district where these are obtainable—indeed with the exception of Slate—which could be examined apart from considerations as to its origin—it is very questionable whether, under any other circumstances, the Metamorphic rocks should be dealt with at all. If the district is one in which Metamorphic rocks occur, an examination of the Schists should precede that of the Slate.

XVI.—THE WEATHERING OF ROCKS.

By the term **weathering** is meant the effect which all kinds of meteoric action have upon the superficial parts of rocks, causing a disintegration of the surface, and a loosening and crumbling of the stone.

Effects of heat and cold. Heat causes rocks to expand, cold causes them to contract. The amount of contraction and expansion, moreover, varies considerably with different minerals. In many countries—notably in certain parts of our own—the daily and seasonal changes of temperature are considerable. Hence, in all rocks exposed to the sun's rays, there is constantly taking place an increase or diminution of volume, by the expansion or contraction of some portions more rapidly than others: this has the effect of gradually tearing apart the constituents of which the rock is composed. The surface is connected with a loose crumbling crust, which tumbles off and subsequently undergoes further disintegration. The cracks and fissures, with which the mass gradually becomes traversed in all directions, form passages for the admission of air and water, which further assist in the process of weathering.

Effects of frost. Almost every known substance diminishes in volume as its temperature is lowered. This is true of water, as it cools from boiling point to 4° C.; at this temperature, however, it begins to expand, and, at the moment of its conversion into ice, its volume increases to such an extent that nine cubic inches of water become about ten of ice. The force developed by this expansion is well nigh irresistible, so much so that strong steel vessels filled with water and closed by screw stoppers have been burst by it. In this way, the water freezing in rock-crevices is able to force their sides further apart, and carry the fissures deeper into the rock-mass. Pieces, both large and small, are broken off, thus exposing fresh surfaces to the action of weathering agents. Even if but few fragments are detached, the rock in time becomes friable and disintegrated, for, when the frozen water thaws, there is nothing to force the displaced particles back into their former positions.

Water. By far the most important weathering agent is water. We have already seen what a powerful factor it is in tearing asunder rock-masses at the moment of its conversion into ice. In other ways its action is even more noticeable—some of which will now be detailed.

The condensed vapour of the atmosphere descends upon the land as rain, hail, or snow. The rain either sinks underground and appears again as springs, or pours down the land-slopes, feeding brooks and rivers. The snow, when it falls on higher elevations, gathers in great snow-fields, is pressed together and converted into ice, and moves down towards the plains and valleys in the form of glaciers. These, in the warmer atmosphere of the lower levels, gradually melt, and flow to the sea in turbid streams. Practically the whole of the water precipitated, is in this way returned to the oceans. When it ascends into the air in the form of vapour, it is comparatively free from impurities, but, after being condensed, descending through the air, and making its way under the surface of the ground, it is no longer pure, but is laden with material collected on its journey. The presence of these impurities immensely increases its weathering properties.

Water acts in two ways—**chemically** and **mechanically.**

Chemical action. On its passage through the air, the rain absorbs several of the gases of which the air is composed—notably Oxygen and Carbon-dioxide. As soon as it reaches the ground, it begins to absorb other impurities from decomposing organic substances in the soil, amongst which are **ulmic** and **humic** (organic) acids. By means of these — Oxygen, Carbon-dioxide, and organic acids—it is able to work many chemical changes it would be unable to accomplish if it were pure water.

All rocks are more or less soluble in pure water, some, *e.g.*, Rock-Salt and Gypsum, being removed with relative rapidity. When, however, the water is charged with the impurities just mentioned, its solvent power is much increased. The presence of dissolved Carbon-dioxide enables it to attack Limestone and carry it away in solution. In many Sandstones and Clay-rocks the cement binding the particles together is Carbonate of Lime; this is acted on by the carbonated water and gradually removed, so that the whole mass in time becomes loose and friable.

Then, again, about one-fifth of the air consists of Oxygen gas, a body very active in promoting the decay of rocks. Oxygen has a great affinity for most substances, readily uniting with them and forming **oxides**; its combination with Iron is known as rust. The Iron and other constituents which occur in many rocks are attacked by the Oxygen, and the oxides thus formed carried away in solution. The result of this is not only the removal of a portion of the rock, but the exposure of fresh surfaces to the action of weathering agents. Most of, if not the whole of the Oxygen concerned in these changes, is carried by water.

Most igneous rocks are formed largely of a mineral called Felspar, which is a double silicate of varying composition—according to the kind of Felspar: it may be a silicate of Potash and Alumina, or Lime and Alumina, or Soda and Alumina, or all of these substances—Potash, Lime, Soda, Alumina, and Silica—may appear in the Felspars of a single rock. Suppose, as in Granite, the Felspar consists of a double silicate of Alumina and Potash (*i.e.*, a compound of Potash and Silica, and Alumina and Silica). The carbonated rain-water has the power of breaking down the link which binds the two compounds together, and of decomposing one of them—the Silicate of Potash. This is converted into Carbonate of Potash, which, being soluble, is quickly carried away in solution. Much of the binding material uniting the particles is in this way removed, so that the rock becomes loose and crumbling, admitting air and water, which continue the process of disintegration. The double silicates occurring in **basalt, andesite,** and other igneous rocks are acted on in a similar way. It is unnecessary to enter into further details, suffice that there are but few minerals which are not attacked by water containing impurities (Carbon-dioxide, Oxygen, and organic acids), and decomposed into simpler compounds, some of which are soluble.

Mechanical action. We have already seen how frozen water or ice acts on rock masses—running water has the effect of removing the weathered crust and so exposing additional surface to further decomposition. This it does by washing away the loosened particles, the heavier the rainfall, the greater being the effect produced.

And not only are the disintegrated particles of rock removed—the soil itself is continually being washed away and carried into the streams. The lower limit of the soil in this way gradually travels down into the sub-soil, which in turn encroaches further on the underlying rock. The net result of all this is that the upper portions of the soil are slowly but surely being carried to the sea, and the soil itself, which would otherwise become exhausted, is constantly replenished by additions from the underlying sub-soil and rock.

Action of roots. It frequently happens that roots find their way into crevices where the expanding force due to growth is sufficient to widen and deepen the fissure or even to wedge pieces off the rock. The organic acids which exude from the roots or rootlets, moreover, have the power of dissolving or decomposing many rock ingredients. The chemical action of water is increased by the roots holding the moisture, and causing it to remain for a longer time on the spot.

Under certain conditions, when for instance the underlying rock is sufficiently close to the surface to be reached by the roots, the effects of root-action are very marked.

The process by which the solution of mineral constituents is brought about by the agency of roots, can be observed on a small scale by placing on a slab of marble a few seeds of, say, cress, and covering these with a thin layer of moist earth. As the seeds germinate and the roots spread, the acids exuded by the root-hairs have the effect of dissolving those portions of the marble with which they come into contact. If the earth and seeds be now removed, the markings caused by the action of the roots can be seen.

NOTE.—The general process of weathering can be observed in most exposures of rock where the surface in colour, hardness, and other properties will be found to differ from the clean fresh appearance presented by the same rock when broken into.

The process should be observed in the field; no amount of talking will convey the same clear and lasting impression as a visit to some crumbling rock-mass, where perhaps the entire transition from rock to soil can be observed.

The chemical changes should be illustrated by experiment when possible—thus oxidation can be shown by exposing the bright surface of a piece of iron *(a)* to the dry air of a room for a few days, and *(b)* to the moist out-door atmosphere for a couple of nights. From this will be learnt not only that oxygen unites with iron to form an oxide, but also that oxidation is much more rapid in a moist atmosphere—*i.e.*, that water is the vehicle which carries oxygen.

Again the solubility of limestone in carbonated water can be made clear, by passing a stream of carbon-dioxide through water holding carbonate of lime in suspension. In a limestone district the furrows traversing the surface of rocks should be noticed and explained.

The action of water in carrying away loosened particles and sediment may be exemplified by referring to the work done on the roadside or in the playground during a shower of rain.

The action of frost can be shown by immersing in a freezing mixture (made by mixing together salt and snow or salt and ice) a test tube filled with water. In a short time the temperature of the water will be lowered, and the liquid itself converted into ice—when the expansion of the water during the process of freezing will crack the test tube. In this connection reference should also be made to the bursting of water pipes in frosty weather.

In fact numerous ways of illustrating this phase of the subject will occur to the thoughtful teacher. Every advantage should be taken of local conditions to make the subject real, and to encourage pupils to question Nature and watch for her answers.

XVII.—THE FORMATION OF SOIL.

The soil is formed from the rocks, and the sub-soil may be considered intermediate between the two. In many places—road cuttings, river-banks, sea-cliffs, land-slips,—the transition from the one to the other is plainly to be seen, the soil giving place to sub-soil, which gradually becomes more compact and harder until it merges into the underlying rock.

The disintegrating action of weathering agents is not confined to bare and exposed rock-surfaces, but is still continued below the weathered mass. Indeed, owing to the greater ease with which weathering agents can obtain access to the material composing the crumbling crust, decomposition and disintegration are there carried on with increased rapidity. Other agents now begin to take part in the process. Seeds germinate, and, sending down their roots, work still further on the fabric of the soil. This becoming mixed with leaves, twigs, and rootlets, gradually obtains a supply of decaying vegetation, which eventually leads to the formation of **humus.**

The work of the Earthworm, in the formation and improvement of soil is deserving of special mention ; for an account of this see Part II., page 104, " The Earthworm."

The soil, then, consists of mineral or inorganic matter, and humus or organic matter ; the former is derived from the decomposition of rocks, and the latter from the decay of animal and vegetable substances. Heat a small quantity of garden mould over a hot flame. The soil should first be dried to remove as much of the moisture as possible, and the flame should be strong enough to raise it to a red heat. Notice the strong smelling smoke being given off, and continue to heat until this ceases to appear. If the dry mould be weighed before and after being " burned," it will be found to have lost considerably in weight, the loss being due to the material which formed the smoke : this is the organic matter or **humus** ; that which remains is the **inorganic** or **mineral matter.**

The most abundant mineral ingredients in the soil are sand and clay. Limestone to a less extent is also sometimes present. Sand consists almost entirely of silica, so that a soil composed of sand would be useless to the cultivator, for it is lacking in plant food—moreover, it is so loose and porous that plants would be unable to get sufficient hold for their roots, and would pine away from the absence of moisture, which sand is unable to retain. It is, however, of considerable use when mixed with clay and other constituents, for it tends to make the soil light and porous, thus admitting moisture, air, and warmth. The presence of sand is helpful in another way ; the particles of which it is composed become heated by the rays of the sun and so tend to raise the temperature of the soil.

The chemical composition of clay is not so simple as that of sand. Pure clay consists of silica and alumina, both composed of oxygen, with a certain proportion of water; hence as a source of plant food it would be as useless as sand. But clay is rarely pure—a number of impurities being almost invariably present—these usually contain elements such as calcium, potassium, magnesium, and iron, which are so essential for the nutrition of plants. Clay is firm and tenacious, does not easily become heated, is able to retain moisture, and so is specially adapted for resisting a drought.

A soil composed entirely of clay would be damp and cold, and would tend to become muddy, for the rain, as it fell on the clay, would be unable to drain away. As one of the constituents of soil, however, clay possesses many useful properties — thus it retains moisture, thereby preventing the soil from becoming dry; it makes the soil firm and tenacious; it absorbs and holds many of the useful products resulting from the decomposition of manures; and it contains many substances useful as plant food.

XVIII.—SAND AND CLAY.

Useful lessons could be given under this heading either to senior or junior classes, (the class depending on the method of treatment)—the subject will furnish plenty of opportunity for establishing comparisons and contrasts. From what has already been said, there will be no difficulty in working out the following.

Sand is composed of little grains, will not bind together even when wet, offers but little hold for the roots of plants, is exceedingly porous and hence will not hold moisture, is derived from the disintegration of rocks, and settles down quickly in water.

Clay is made up of exceedingly fine particles which readily bind together when wet; hence when moist it is plastic and can easily be moulded into any shape—is compact, feels smooth and greasy; when dry, adheres to the tongue, is hard and permeable to water which it readily absorbs; when saturated, becomes impermeable to water; retains moisture for a long time; when burnt, becomes hard and porous, readily absorbing water which passes through without softening the material; is derived from the disintegration of rocks; settles down slowly in water.

NOTE:—The work should of course be dealt with in such a way that pupils will be led to find out for themselves the properties of the two substances. The methods of treatment necessary for this result will readily suggest themselves to the teacher.

KINDS OF SOIL.

Soils rarely consist of one constituent only—nearly all soils being made up of varying proportions of sand, clay, lime, and humus. As, however, sand and clay occur in much greater quantities than any of the other constituents, it has been found convenient to classify soils according to the amount of these substances they contain—thus if the soil consisting almost entirely of sand and clay contains about 90 per cent. by weight of sand, it is said to be a **sandy soil.** If from 10 to 40 per cent. of clay, it is a **sandy loam**; if from 40 to 70 per cent. of clay, it is a **loamy soil**; if from 70 to 85 per cent. of clay, it is a **clay loam**; if from 85 to 95 per cent. of clay, it becomes a **clay soil.**

NOTE:—A **loam** may be defined as a soil consisting of sand and clay, in which there is an appreciable amount of both constituents.

When carbonate of lime is present in quantity ranging from 5 to 20 per cent. the soil is called a **marl**; when a higher percentage is present, the name given is a **calcareous soil.**

For nearly all purposes of cultivation a loamy soil is best —and one, moreover, which does not contain an excessive percentage of either sand or clay—in other words a medium loam. Hence the operations of the skilful cultivator are directed towards bringing the soil into this condition.

CHEMICAL INGREDIENTS OF SOILS.

We have already seen that soils contain silica, alumina, and lime. Other ingredients usually present are magnesia, oxide of iron, potash, soda, phosphoric acid, sulphuric acid, and chlorine. One of these, chlorine is a gas; all of the others are oxides, that is, compounds of oxygen with some other element, though in the case of the acids, water also enters into the composition.

Chlorine is an element, (gas).

Magnesia is a compound of the metal magnesium, and oxygen.

Oxide of iron is a compound of the metal iron, and oxygen.

Potash is a compound of the metal potassium, and oxygen.

Soda is a compound of the metal sodium, and oxygen.

Sulphuric acid is a compound of the mineral sulphur, oxygen, and hydrogen.

Phosphoric acid is a compound of phosphorus, oxygen, and hydrogen.

With the exception of oxide of iron, none of these substances usually exist **free** in the soil—that is, soils do not contain potash, soda, or lime as such, but hold them in combination with other substances. The chemical ingredients in fact exist in the form of **salts**—a salt being a substance formed by the union of an acid with a base.

For instance the **base magnesia** unites with the **acid carbonic acid** to form **carbonate of magnesia,** and the **base lime** unites with the **acid phosphoric acid** to form **phosphate of lime.** The resulting compounds carbonate of magnesia and phosphate of lime are known as **salts.**

Of the various substances required for the nutrition of plants, there are four of which the available supply is likely to run short, so that the cultivator has to be continually making good the deficiency. These are **phosphoric acid, potash, lime,** and **nitrogen.** The three former are mineral ingredients, for they occur naturally in the soil. Nitrogen is derived from the decay of **organic matter** in the soil, though small quantities in the form of ammonia—(a compound of nitrogen and hydrogen) and nitric acid (a compound of nitrogen, oxygen, and hydrogen) are brought down dissolved in rain.

Local and Transported Soil.

When a soil is derived from the decomposition or weathering of the underlying rock it is known as a **local** soil; when, however, it bears no relationship to the rock, lying beneath, but has been brought to its present position from elsewhere it is called a **transported** soil.

An examination of the soil of a district, especially in cuttings, river channels, land-slips etc., where the exposures are fresh, will in most cases reveal its origin. The alluvial flats forming such extensive tracts in many of our river valleys furnish good examples of transported soil. In nearly all cases the agent concerned in the removal and deposition of soils is water.

NOTE :—Some little time should here be devoted to revising the lessons already given on the Earthworm in order to bring home the important part which this animal plays in the production of humus and the formation of soil.

The general characters of the soils in the neighbourhood might be determined *e.g.* whether light or heavy—whether sandy soils or clay soils, or loams.

The examination of gravel pits, shingle beds, and quarries, will often determine whether the soil be local or transported.

The formation of a salt by the union of an acid and a base is capable of simple demonstration. Take a bottle of soda-water and, after uncorking, allowing the effervescence to subside, and diluting the liquid, pour some of it into a vessel containing lime water. The whole at once becomes milky owing to the presence of the insoluble carbonate—that is, the **acid** carbonic acid has united with the **base** lime to form the **salt** carbonate of lime.

The soda-water must not contain too much carbon-dioxide as carbonate of lime is soluble in water holding an excess of this gas in solution.

In each case the solutions are colourless—so that the sudden appearance of the precipitate will illustrate the change which has taken place.

Salts may also be formed by the action of an acid on a metal. Place a few pieces of granulated zinc in a beaker and add a small quantity of dilute hydrochloric acid. Bubbles of hydrogen gas will be given off and the zinc will gradually disappear. Filter the solution and observe the clear colourless filtrate. Pour this into a porcelain crucible and evaporate over a bunsen or spirit-lamp flame. Notice the deposit left at the bottom and on the sides of the crucible—a substance differing entirely from the original zinc. The hydrochloric **acid** has combined with the **metal** to form the **salt, zinc chloride.** If sulphuric acid be used, the salt formed will be zinc sulphate.

The reactions between certain acids and salts may be used for purposes of further illustration. Dissolve a few crystals of barium chloride in some water, and into a very weak solution of this pour a few drops of dilute sulphuric acid—a dense white precipitate will at once appear. The sulphuric acid has united with the barium to form the insoluble **salt, barium sulphate.**

The reactions which result in the formation of an insoluble salt, and which therefore can be seen taking place by a class, are perhaps the best for purposes of illustration.

Appendix.

Composition of the Atmosphere.—The atmosphere—an invisible elastic fluid surrounding the earth—is a mechanical mixture of watery vapour and a number of substances principally gases, the chief of which are oxygen, nitrogen, and carbon-dioxide. The proportion of these per 100 volumes is approximately

Oxygen	20·80
Nitrogen Argon	79·16
Carbon-dioxide	·04
	100·00

In addition to these there are present, as essential constituents, ammonia, ozone, and nitric acid. Other substances—accidental impurities as they are called—are sometimes present, the chief of which is sulphuric acid.

Composition of Water.—Water is a chemical compound of two gases, oxygen and hydrogen, in the proportion of one volume of oxygen to two volumes of hydrogen.

Since oxygen is approximately sixteen times heavier than hydrogen, it follows that these gases must be present in water, in the proportion of sixteen parts by weight of oxygen to two parts by weight of hydrogen, *i.e.* in the proportion of 8 to 1.

For a more detailed account of these substances, and for methods of determining the proportion in which the gases enter into the composition of air and water, the reader is referred to some treatise on chemistry. In the upper classes it will probably be necessary to discover these proportions by experiment, as also to investigate the properties of the gases.

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